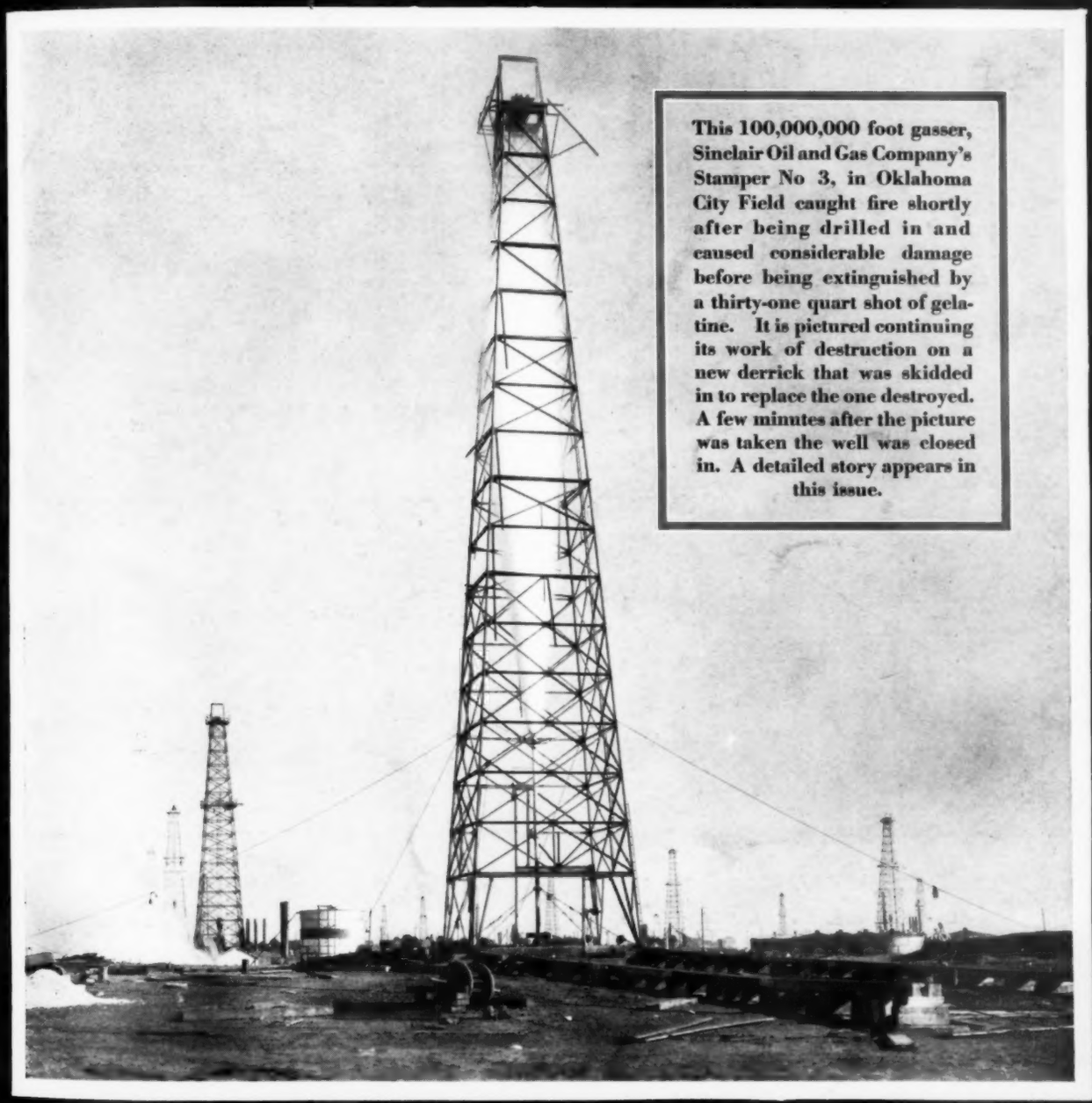

This 100,000,000 foot gasser, Sinclair Oil and Gas Company's Stamper No 3, in Oklahoma City Field caught fire shortly after being drilled in and caused considerable damage before being extinguished by a thirty-one quart shot of gelatine. It is pictured continuing its work of destruction on a new derrick that was skidded in to replace the one destroyed. A few minutes after the picture was taken the well was closed in. A detailed story appears in this issue.

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Petroleum Engineer

The Engineering Magazine of the Oil and Gas Industry

Volume 1 NOVEMBER, 1929 Number 2

This issue contains

	Page
The Month's High Lights in Oildom By J. L. Dwyer	19
Completion and Control of High Pressure Wells By K. C. Sclater	20
The Texas-Empire Pipe Line to Chicago By J. H. Dameron	23
The Manufacture of Bright Stocks By F. R. Staley	26
Making New Pipe Lines Out of Old	28
Refinery Pollution Control By W. C. Smith	31
Modern Pipe Line Construction By E. F. Schmidt	34
Control of Refinery Operations with Instruments By F. M. Poole	40
Automatic Gas Well and Main Line Drip By Robert Wetzel	48
Extinguishing a Burning Gas Well	51
Tubing High Pressure Wells By H. C. Otis	53
The Manufacture of Premium Gasoline	63
Quantitative Effect of Gas-Oil Ratios	68
Some Principles of Flowing Wells By S. F. Shaw	78
The Gum in Gasoline By Vilkas and O'Neill	82
Spacing of Wells in the Long Beach Field	87
Vacuum Distillation in Production of Lubricating Oils	90
Gyroscopic Instruments for Well Surveying By S. H. Williston	95
Flowing Oil Wells By I. B. Williams	100
Flow Resistance Through Vertical Pipes	104
Vapor Phase Cracking	109
An Explanation of Internal Combustion Engines By E. H. Crosson	113
Condensation Effects in Determining Gas-Oil Ratios	180
Re-Pressuring Practice in the Mid-Continent Field	184
Electric Welding of Pipe Lines	190
New Type Rotary Being Developed	200
Handling Gas Well Craters	202
Taking the Kinks Out of Crooked Holes	206

REGULAR DEPARTMENTS

New Petroleum Equipment—	116, 117, 119, 122, 124, 125
New Patents of the Industry	208, 209
Running Tour With Men in the Industry	128, 129
Laugh With Barney	126
Pictorial Petroleum	131-178 inclusive

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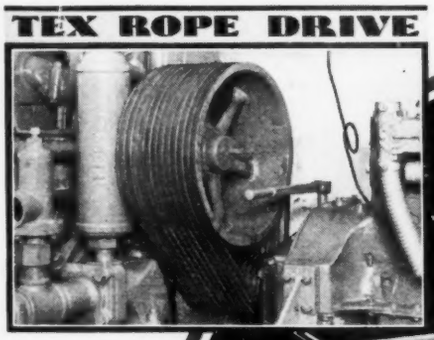
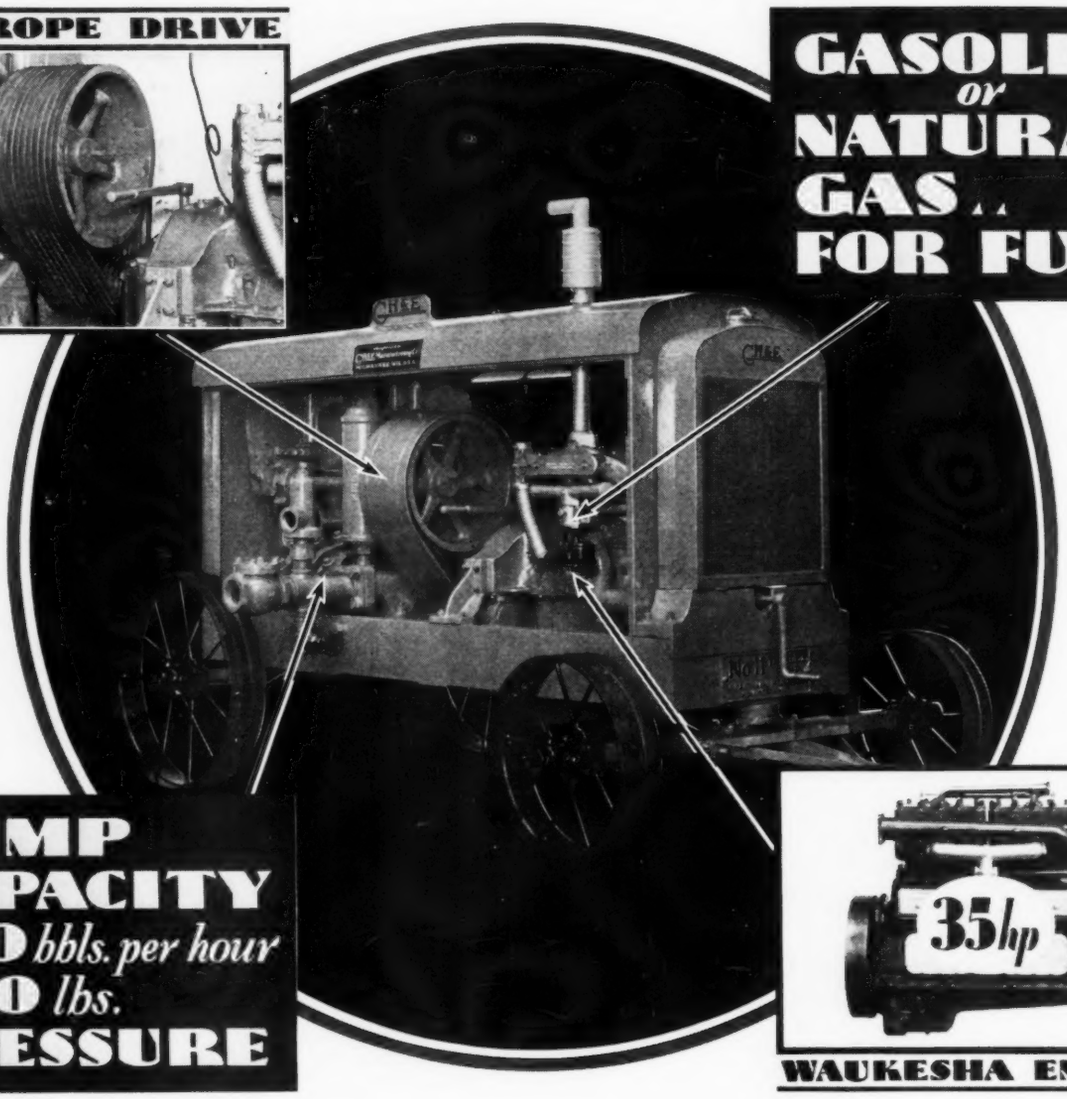
C.H.&E. *for* ALL ... PUMPING CONDITIONS





This unit has proven of great value in furnishing water for both Rotary and Standard drilling. Exceedingly portable, and ready for all emergencies. A few of the more important features include a vertical type 4¼"x5½" Triplex Pump with the water box below preventing cutting of the plungers, a heavy drop-forged crankshaft carried on roller bearings, special metallic valves which will not warp, corrode or pit and are easily accessible. Bulletins are available giving complete information on this unit, and will be gladly mailed at your request.

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THE MONTH'S HIGH LIGHTS IN OILDOM

By J. L. DWYER

CALIFORNIA continued to hold the attention of the industry last month. When no relief from the top-heavy producing situation on the Coast was apparent, substantial crude price reductions were announced in the fields which were believed to be exerting adverse market influences. The price changes were effective October 21, and their announcement was immediately followed by a series of conferences which greatly clarified the situation. The California operators have agreed to reduce the state's production by 203,000 barrels daily, and this action will very likely restore the price structure to its former level. Had the California situation remained unimproved other fields were doomed to experience lower crude prices.

The elimination of 200,000 barrels of oil daily from the nation's output will improve our industrial situation. It will mean that stocks may experience a reduction, and this is a condition which has been desired since 1923. In a recent statement, E. B. Reeser, president of the American Petroleum Institute, placed the United States' daily petroleum supply at 3,100,000 barrels, and the daily requirements at 2,966,000 barrels. At this rate crude stocks are being increased by 134,000 barrels daily. If production is lowered by 200,000 barrels, stocks may be reduced 66,000 barrels daily.

Pure Oil Makes Important Discovery

An important event of the month was the Pure Oil Co.'s discovery of production in Van Zandt County, Texas. This well flowed 2,500 barrels daily from the Woodbine sand, a very prolific formation. The area has exceptional geological recommendations, and the find is considered highly important. It is located in East Texas near the Louisiana line.

By the end of November, the Oklahoma City field will probably have additional pipe line outlet for 40,000 barrels of oil daily. The order of the Oklahoma Corporation Commission calls for prorating 50 per cent of this pool's production during December.

Wells of high initial output continue to be brought in at Oklahoma City. Recent events in that field indicate that the highest types of equipment will be needed to handle satisfactorily the high pressures encountered in that area. Recently one well completed by the I. T. I. O. flowed one thousand barrels in 15 minutes, or at the rate of 96,000 barrels daily.

The refining situation shows very little change. According to the A. P. I. figures, the nation's refineries were running 83.9 per cent of their capacity daily during the last week in October. This is a slightly lower percentage than they were running one month previous. With winter weather at hand, and the peak gasoline consumption season in the background, a drop in refining activities might normally be expected.

Pipe Line Deliveries Changing

A recent U. S. Bureau of Mines circular contains the information that pipe line deliveries of Mid-Continent crude to Atlantic Coast refineries showed a marked decrease in the past year; dropping from eleven million barrels to three million barrels annually. When it is remembered that the lines have been running to capacity, this statement gives evidence of the changing condition. The Mid-Continent crude is finding additional markets in the Great Lakes region and at inland refineries. This is borne out by the broad pipe line construction program from the Mid-Continent to the Great Lakes which has been in progress.

Production and Refining Figures Furnished by the American Petroleum Institute

Crude Runs to Stills, Gasoline and Gas and Fuel Oil Stocks, Week Ending October 26

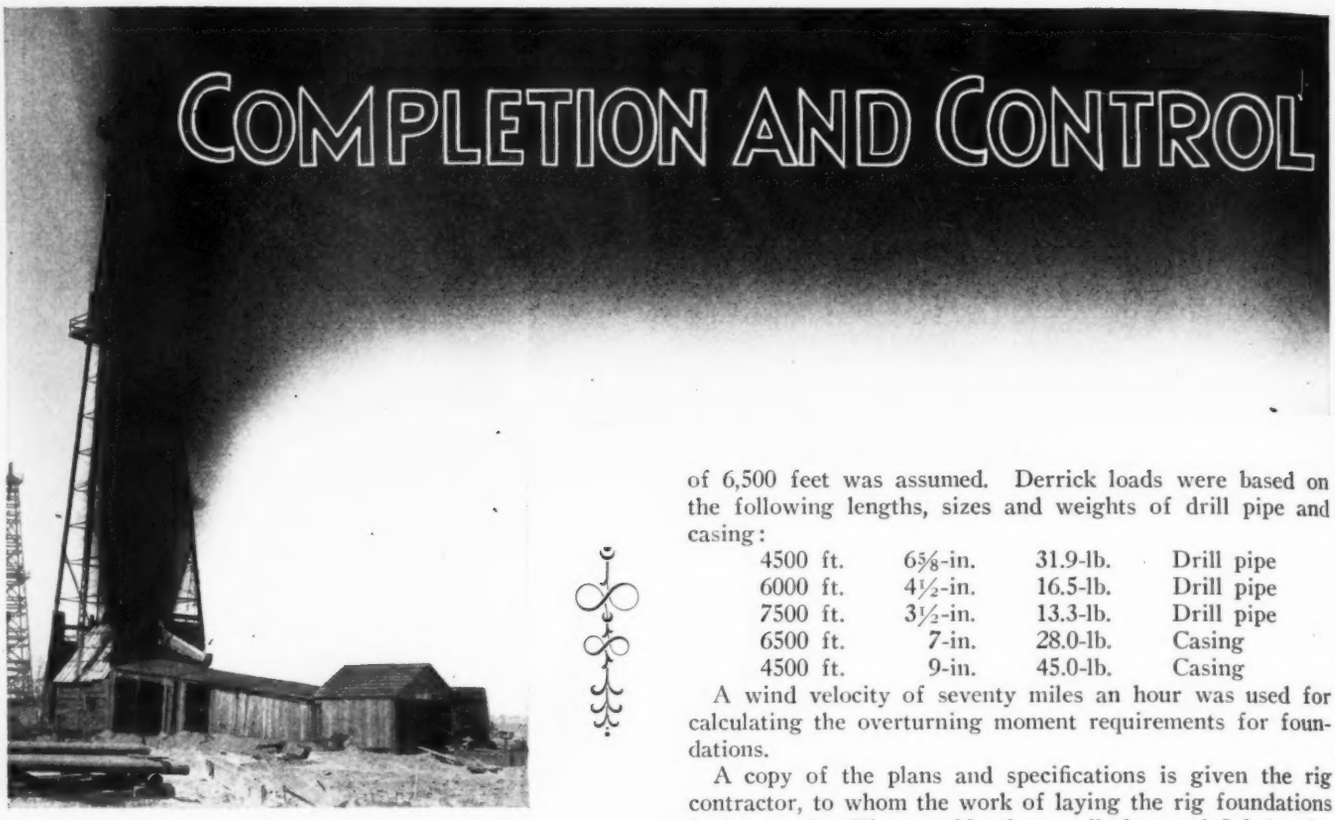
(Barrels of 42 Gallons)

DISTRICT	Per Cent Potential Capacity Reporting	Crude Runs to Stills	Per Cent Operated of Total Capacity Reporting	Gasoline Stocks	Gas and Fuel Oil Stocks
East Coast	100.0	3,471,100	83.8	4,130,000	9,182,000
Appalachian	88.1	675,600	87.8	759,000	760,000
Ind., Ill., Ky.	98.4	2,136,100	86.2	4,090,000	3,802,000
Okla., Kan., Mo.	88.2	2,030,900	76.6	2,224,000	4,113,000
Texas	91.6	4,246,100	89.5	4,934,000	14,160,000
Louisiana-Arkansas	97.1	1,336,200	72.2	1,680,000	4,983,000
Rocky Mountain	93.2	468,400	54.0	1,629,000	944,000
California	98.7	5,199,000	89.5	13,356,000	110,011,000
Total Wk. Oct. 26	95.4	19,563,400	83.9	32,802,000	147,955,000
Daily Average		2,794,800			
Total Wk. Oct. 19	94.9	19,592,000	85.1	32,160,000	146,421,000
Daily Average		2,798,800			
Texas (Gulf Coast)	100.0	3,281,300	92.2	4,193,000	10,793,000
La. (Gulf Coast)	100.0	901,200	73.1	1,399,000	4,228,000

Daily Average Production

(Figures in Barrels)

	1929 Oct. 26	1929 Sept. 21	1928 Oct. 27
Oklahoma	680,650	698,600	738,050
Kansas	110,700	128,850	97,200
Panhandle Texas	104,600	121,950	68,650
North Texas	91,900	96,600	90,100
West Central Texas	58,000	58,250	55,150
West Texas	363,400	366,300	335,650
East Central Texas	18,000	18,000	22,200
Southwest Texas	74,850	73,250	26,600
North Louisiana	38,200	36,700	38,550
Arkansas	63,950	64,700	83,250
Coastal Texas	147,300	133,700	113,150
Coastal Louisiana	23,700	22,650	19,500
Eastern	119,800	137,500	112,600
Michigan	18,100		2,400
Wyoming	53,350	55,400	63,900
Montana	10,950	11,500	12,350
Colorado	5,350	6,500	7,300
New Mexico	6,400	3,550	1,900
California	880,500	890,500	635,200
Total	2,869,700	2,924,500	2,523,700



COMPLETION AND CONTROL

WITH well depths in excess of six thousand feet, hard drilling formations, and rock pressure of 2,350 pounds, proper completion and control of wells in the Oklahoma City Field demand the best in drilling equipment and a high degree of skill and caution. To place wells on a successful production basis, operators in the field fully realize the drilling conditions and hazards that confront them. This has led to the adoption of drilling methods and equipment which set a high standard in deep rotary drilling practice.

A cursory inspection of the 150 odd wells drilling in the field at the time of this writing, conveys to an observer a remarkable uniformity in the type of equipment and methods in use by all operators.

A scene near the West Texas oil country where you look far and see little.

Typical of good development practice in this field are the methods followed by The Indian Territory Illuminating Oil Co. This company, realizing at the very outset, the advantage and necessity of making an early decision regarding the most suitable type of equipment and methods to adopt, before their drilling campaign got too far under way, had their engineers make a thorough and systematic investigation and study of field conditions and requirements. One of the results of this investigation was the drawing up of complete plans and specifications for concrete rig foundations. These are in use by this company, and are shown on Fig. 2 accompanying this article.

Concrete Rig Foundations

The derrick foundations are designed for a 123-ft. combination steel derrick which complies with A. P. I. Standards for strength, materials and workmanship. A well depth of 6,500 feet was assumed. Derrick loads were based on the following lengths, sizes and weights of drill pipe and casing:

4500 ft.	6⅝-in.	31.9-lb.	Drill pipe
6000 ft.	4½-in.	16.5-lb.	Drill pipe
7500 ft.	3½-in.	13.3-lb.	Drill pipe
6500 ft.	7-in.	28.0-lb.	Casing
4500 ft.	9-in.	45.0-lb.	Casing

A wind velocity of seventy miles an hour was used for calculating the overturning moment requirements for foundations.

A copy of the plans and specifications is given the rig contractor, to whom the work of laying the rig foundations is intrusted. The specifications call for a 1-2-3½ mix, (1 cu. ft. cement, to 2 cu. ft. sand and 3½ cu. ft. aggregate) and a mixing time of not less than two minutes. For each rig foundation a total of 110 cu. yds. concrete is required. Sand reel foundations are so designed that holding-down bolts can be taken out when the sand reel is removed. All foundations are designed for heavy steel rig fronts. Steel derrick floor sills are also being tried in order to reduce the fire hazard. All derrick corners are carefully leveled with a level or transit. A slight departure from A. P. I. Standards is the centering of the rotary table in the derrick base instead of placing it six inches off center toward the Sampson post. This is done because of the steel front used. An advantage in derrick strength is also gained, since, except for drilling out the cement plug with standard cable tools, the entire work is done with the rotary tools.

Type of Drilling Equipment

Following general practice in the Mid-Continent, the drilling is all let out on contract. Boiler battery installation consists of four 125-H. P. 250-lb. pressure boilers, or three 125-H. P. 300-lb. pressure boilers. All boilers are lagged with about a three-inch thickness of asbestos. All boiler-feed pumping equipment, tank and connections, are conveniently located directly in front of the boilers, and are well housed in a corrugated sheet iron building which extends over the front half of the boilers. A feature of the boiler house equipment is the compact and standardized arrangement which is followed out at all wells.

The boiler-feed pumps, two 10x4½x10 reciprocating type,

OF HIGH PRESSURE WELLS

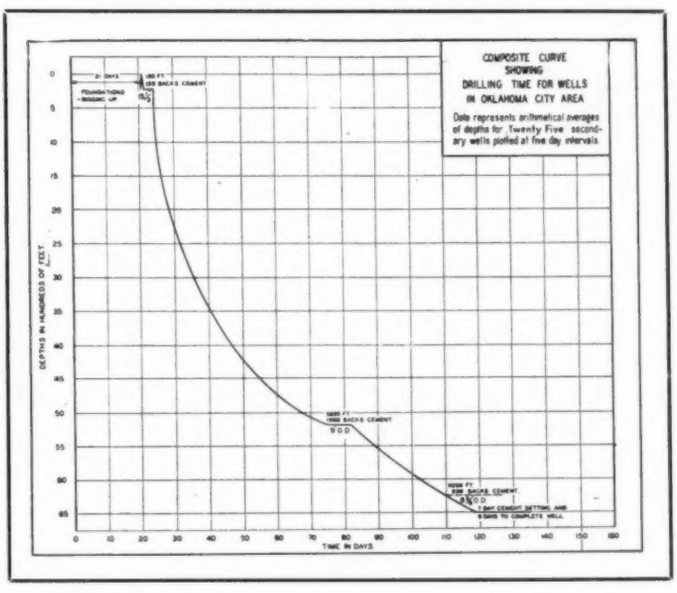
by K.C. SCLATER

together with two rig-lighting turbine generator sets, are mounted on heavy steel beams to facilitate quick installation and removal. A steel rectangular feed-water tank, feed-water manifold, steam traps, gas regulators and low-pressure burner controls are all arranged so as to obtain the most efficient operation. The mounting of the feed pumps and lighting sets on steel beams and the construction of steel feed-water tank and manifold connection are all done in the drilling company's shop, thus reducing field labor installation and operating costs to a minimum. Great savings and convenience in operation are also gained by standardizing boiler installation set-ups, especially where a drilling contractor has a large number of rotary tools in operation.

Motive power for drilling is supplied by 12x12 twin drilling steam engines. Various types of the heaviest and sturdiest rotary drawworks, with the number of speeds varying from three to eight, are in use.

Other equipment worthy of comment are the heavy roller bearing rotaries, including the fully enclosed type running in oil; heavy steel double-deck large sheave crown blocks equipped with antifriction bearings, especially designed for Mid-Continent service; heavy 4-sheave traveling blocks with dual bearings; and weldless elevator links of the latest improved design for handling extra heavy loads.

For about the first 3,000 feet disc bits are sometimes used, from there on rock bits are used entirely until the final string of casing is run and cemented. Most of the contractors prefer to drill with weight indicators only, and exercise close control of the weight on the bit. From about 3,500 feet on, care is taken not to force the drilling, but to hold the weight up as much as possible, commensurate with good drilling speed. The footage obtained per set of rock bit cones varies from sixty to ninety-five feet.


COMPOSITE CURVE
SHOWING
DRILLING TIME FOR WELLS
IN OKLAHOMA CITY AREA
Data represents arithmetical averages of depths for Twenty Five secondary wells plotted at five day intervals
DEPTHS IN HUNDREDS OF FEET
TIME IN DAYS

Good Mud Fluid System Necessary

Strict attention is paid to the weight of mud fluid carried. A continuous check of the mud weight is necessary below 4,000 feet, where high-pressure gas sands are a constant menace in drilling. Weights of drilling mud normally carried vary all the way from 9¼ to 12 lbs., with a probable average of 10½ lbs. per gallon. Large losses of mud sometimes occur through dissipation into porous formation, especially above 3,000 feet, hence it is found necessary at such times to give the mud greater consistency or more weight, or both, by the addition of Mud-wate, Baroid, Iron Oxide, Slush Mix, Aquagel, or other mud-thickening materials.

At frequent intervals the mud is tested for weight. Each drilling well has an elaborate slush pit system, consisting of two or three deep settling pits and a large shallow pit for cuttings. Each settling pit is equipped with a 5 or 6-in. pipe with steam connection for steam jetting the cuttings from the settling pit into the cuttings pit. With this slush pit system, the driller is enabled to maintain his mud fluid system at good efficiency.

When drilling through high pressure gas horizons, the most extreme precautions will often not be sufficient to check "gas-cutting" of the mud fluid. For example, on a well the ingoing mud at pump suction was 10½ lbs., the same mud as it came from the well weighed only 7½ lbs. per gallon. Small bubbles of gas highly disseminated in the mud fluid fluffed it up to the extent that its weight was decreased three pounds per gallon. Here is a field still open for much investigation, a study of the character and properties of mud fluids in rotary drilling.

A good mud fluid should be a good cooling medium, have sufficient weight, should not settle, be a good lubricant, have good sealing properties, have high resistance to "gas-cutting", have good carrying power to remove well cuttings without settling, and in the slush pits the same mud fluid should be able to drop its burden of cuttings quickly without loss of any of its other desirable properties. The two latter requirements are somewhat hard to fill because the desirable property of mud fluid in a well, that of being able to remove cuttings effectively without settling, is somewhat opposed to the property of being able to drop its burden of cuttings required in the slush pits.

When the drill pipe is pulled there is a reduction of the mud fluid level in the well. This reduction is great enough that it constitutes a serious blow-out hazard in the wells as they penetrate the high pressure zones. It is the practice, therefore, while pulling drill pipe in deep drilling wells, to

keep the mud fluid level high enough to overcome the estimated rock pressure.

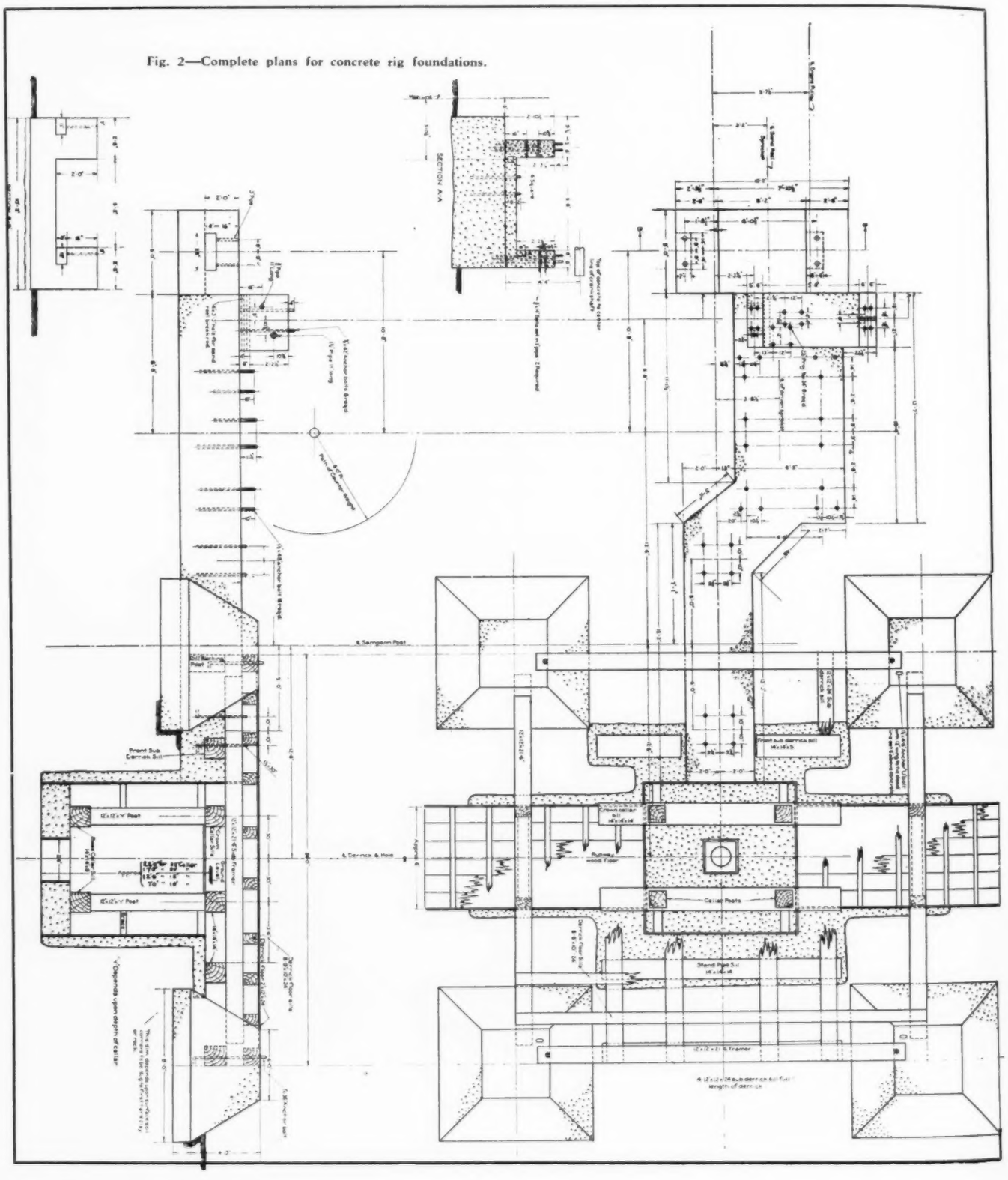
Straight Hole Drilling Practice

Freedom from crooked-hole troubles has marked the development to date of the Oklahoma City Field. It is standard practice with the Indian Territory Illuminating Company to make an acid bottle test every 500 feet during the period the well is being drilled. The acid bottle container is run inside the drill pipe. Tests were made on the first nine or ten wells drilled, at 500-ft. intervals to the bottom of the hole. Below 4,500 feet the deviations were found in all cases to be very slight, never exceeding 2½ degrees, possibly due to the caution exercised by the driller because of the probability of too sudden penetration of high-pressure zone.

On account of the great hazard in running equipment of any description inside the drill pipe below 4,500 feet, and also because observations indicated that the deviations from vertical were small below 4,500 feet in the first wells tested, the practice now is to make acid bottle tests at 500-ft. intervals to 4,500 feet only. If found necessary or advisable, tests are made below this point.

Editor's Note: Mr. Sclater's concluding paper on this subject will appear in next month's issue.

Fig. 2—Complete plans for concrete rig foundations.



Many Novel Features of Construction in

The Texas-Empire Line *to* Chicago

By J. H. DAMERON

CONSTRUCTION of one of the world's largest oil lines during the greater part of 1929 was an outstanding engineering achievement of the transporters during the year. Along this artery's far-flung reach, a few of the line construction problems characteristic of almost every section of the country traversed by oil lines were encountered.

This line was built by The Texas Company, and the Empire Gas & Fuel Co., a Cities Service subsidiary, from the Mid-Continent to supply refineries near Chicago, Ill. Throughout it is built with 12-inch pipe and will start operating with a daily capacity of 40,000 barrels at 750 pounds pressure.

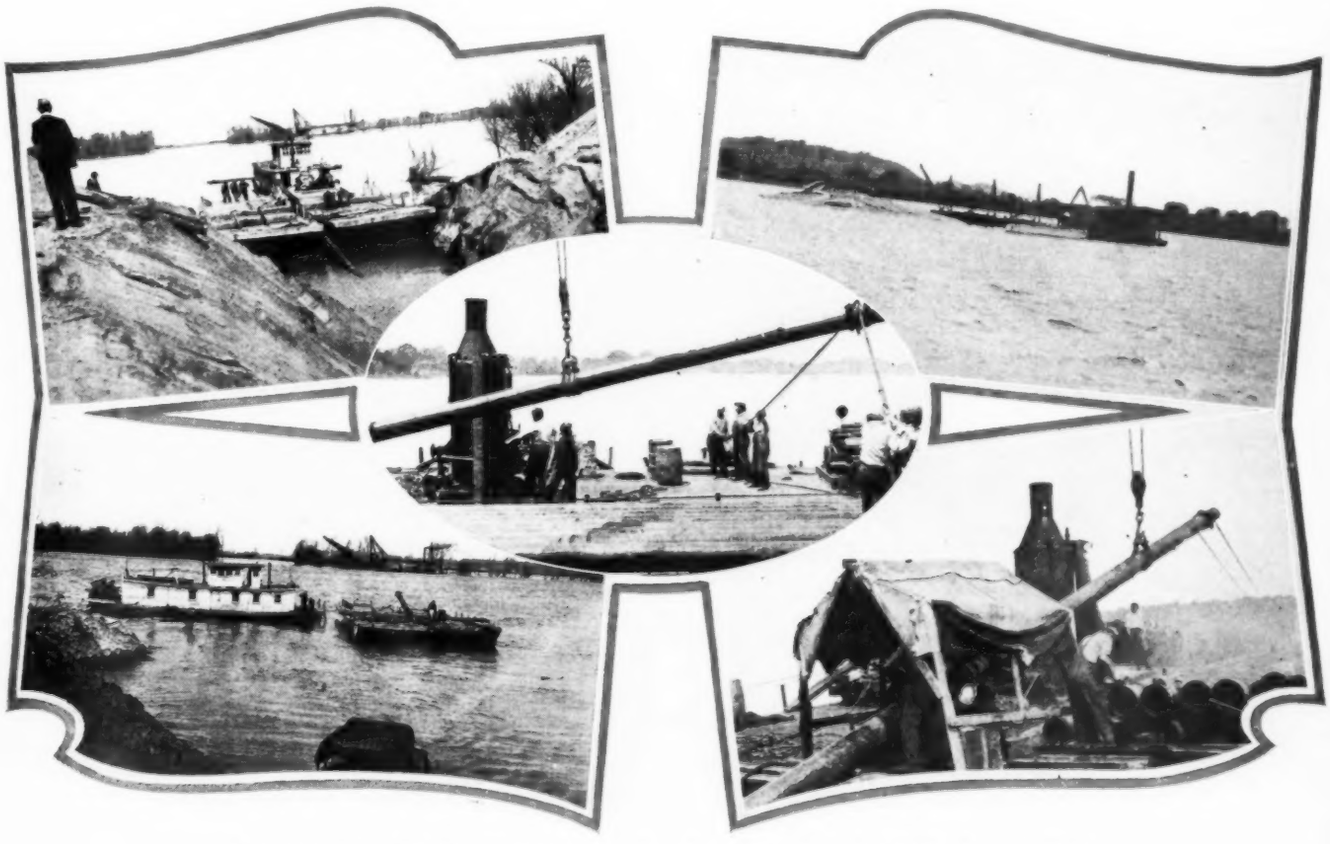
The main line pipe is A. O. Smith bell and spigot 40-pound pipe with a wall thickness of .303 and made with 29-30 carbon steel, in 40-foot joints.

For the purpose of contracting construction, the line was built in eight sections with Sheehan Pipe Line Construction Co. building two sections, Williams Brothers, four sections, and Kelly-Dempsey and Charles F. Ray, one section each. The eight main line stations were constructed by Dresser and Gorton, Long Construction Co. and George P. Reintjes.

To insure good welding inspectors frequently cut samples behind each welder. In some instances a torch was used to cut the welded bell and spigot ends from the pipe, cutting nine inches both directions from the weld, in order to obtain samples for testing its strength. After a section of line was cut out longitudinal strips about an inch and a half in width were cut from four places of the section and then tested with a pulling machine and the character of the fractures noted. After cutting the 18-inch section from the line a split sleeve was placed on one end of the pipe. The ends were drawn together and tack welded. The sleeve ends were welded to the pipe and then the longitudinal seam welded. The frequency of this type of testing depended upon the judgment of the inspectors.

Another method of testing welds was with the use of a coupon slotting machine. With this machine coupons three inches long and $\frac{3}{4}$-inch wide were cut out. The coupons after being polished brightly were then etched with a solution of ammonium persulphate to determine the penetration of the weld. This solution worked ideally in the field since there is little danger of injury from it and the same results are obtained as with the use of more dangerous acids.

For the most part the line was welded in sections of six joints, although some of the sections were made up in from eight to ten joints. The average welding time on the firing



Some scenes in making river crossings on the Texas-Empire line from the Mid-Continent to Chicago.

line was around 45 minutes per weld, the bell-hole welds requiring about 55 minutes.

All line tests were made with hydrostatic pressure, the length of the line tested varying anywhere from eight to 75 miles, but usually the shorter sections were tested. To make these tests the end of the line was bull plugged and the section equipped with air vents. Pumps set up near good sources of water supply, filled the line, building up a pressure of from 800 to 850 pounds and holding this 24 to 48 hours.

In bending pipe to conform to the floor of the ditch, fire bends proved unsatisfactory to the builders, so cold bends were made throughout the entire line despite the large diameter of the pipe and that it was made of high carbon steel. To accomplish this overbends and sags were made by a method not in common use.

To make a fairly sharp sag three tractors were used. Boom tractors were anchored at each end of the pipe and chains lashed to the ends and the tractors' winch lines attached to the chains. Heavy timbers were placed over the low point of the sag to prevent buckling and the third tractor driven directly over this. After the third tractor was in place as many men as necessary climbed on to add weight. The two boom tractors on either end then pulled up on the pipe, making the bend.

Overbends were made with the reverse operation. Two tractors held down the ends while the center tractor lifted up on the pipe. Usually a chain for the third tractor to hook on to was lashed around the pipe, but occasionally this resulted in buckling. Some of the contractors eliminated placing such stress on a small area by bracing the pipe with a split joint of 16-inch pipe which was built with four eye hooks with chains fastened to the hooks. This simple device distributed the stress on the pipe over a greater area.

In making the minor bends a tractor was used to lift the line while a gang walked out on the end bending the pipe. In all cases of bends Mahoney bending irons were used on the welds.

Three major river crossings supplied the most interesting features of construction work as they were made up and put across in a manner somewhat different from the average. For these crossings 12¾-inch bell and spigot 65-pound ½-inch wall 40-foot joint pipe was used. Every weld was reinforced with straps of metal running lengthwise to the pipe. As the line was lowered 1,600-pound river crossing clamps were put on.

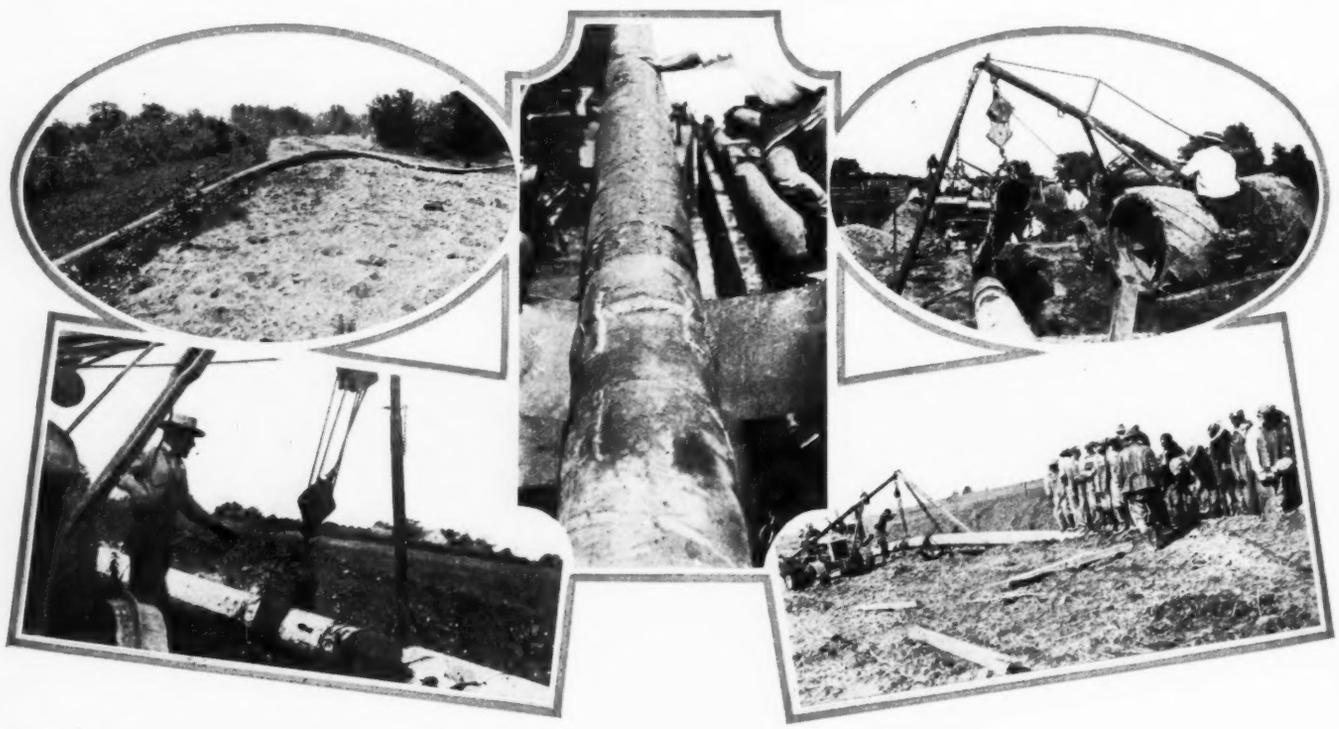
Two lines cross each river a quarter to three-eighths of a mile apart and are curved up stream. Two gates are set in as the line approaches the river bank. One on the main line going across and the other is on the line cut in ahead of the first gate and the second line laid upstream on the bank for approximately a quarter of a mile and then angled into the stream. The same layout is used for the gates on the opposite bank. The gates are 1,600-pound test 12-inch with forged steel flanges welded to the pipe.

The crossing on the Missouri is 2,000 feet from water's edge to water's edge and 4,000 feet of pipe is built in each line. The Mississippi crossing is 3,500 feet from water's edge to water's edge and 4,000 feet of pipe is used in each line crossing that treacherous waterway.

In building the crossings for these two rivers the contractors employed a "little navy". Two barges were lashed together for the construction work. On one was a Dorsey engine, anchored to concrete anchors placed on opposite sides of the river, which was used to propel the two barges. To move, slack was let out on one anchor line and pulled in on the other. Pipe was carried on the other barge. A derrick boat was lashed alongside to lift the pipe and a tug boat did transport duty.

Starting from one shore the welding crew on the barges welded the crossing joint at a time. The derrick boat crane lifted the pipe and lined it up for the tack welders. After tack welding it was held in place until the complete weld was burned in, reinforcement straps welded on and the clamps bolted down. The barges then moved forward to repeat the operation for the next joint.

After sufficient line had been made up for the river crossing and dropped to the bed, a steam-driven centrifugal pump dredge sucked out sand beneath the line, lowering it in conformity with Government specifications. On the Missis-



Upper left, the line crossing a river levee. Center, an unusual weld. Upper right, tractors making a sag. Lower left, canvas sling used to protect pipe coating when lowering. Lower right, making a bend.

sippi the specifications required the line to be 15 feet below the standard low and the specification for the Missouri required the line to be 18 feet below the standard low.

Going across the Illinois with two lines was accomplished in a most unusual manner. At the time the crossing was made the river was at flood stage. A bucket dredge cut out the bank and as far as possible into the stream. The pipe was welded in three sections and pushed instead of pulled across. This method required only two days to complete after everything was ready.

Two barges were lashed together with heavy timbers, allowing only enough space for the pipe to go between. Guide lines were taken across the river and attached to one barge and the tugboat served to keep the barges from drifting downstream. A drag line was hooked on to the pipe and pulling from back shore it pushed the line across the river. The Illinois at this point is 1,600 feet from water's edge to water's edge, requiring 2,000 feet of pipe for each line crossing.

The builders were not permitted to trench in the levees and to cross them the line was welded over the top and an overbend made to conform with the shape of the levee. Each levee was crossed at an angle and an 18-inch mound of dirt thrown on top. All railroad and highway crossings are cased with 16-inch pipe.

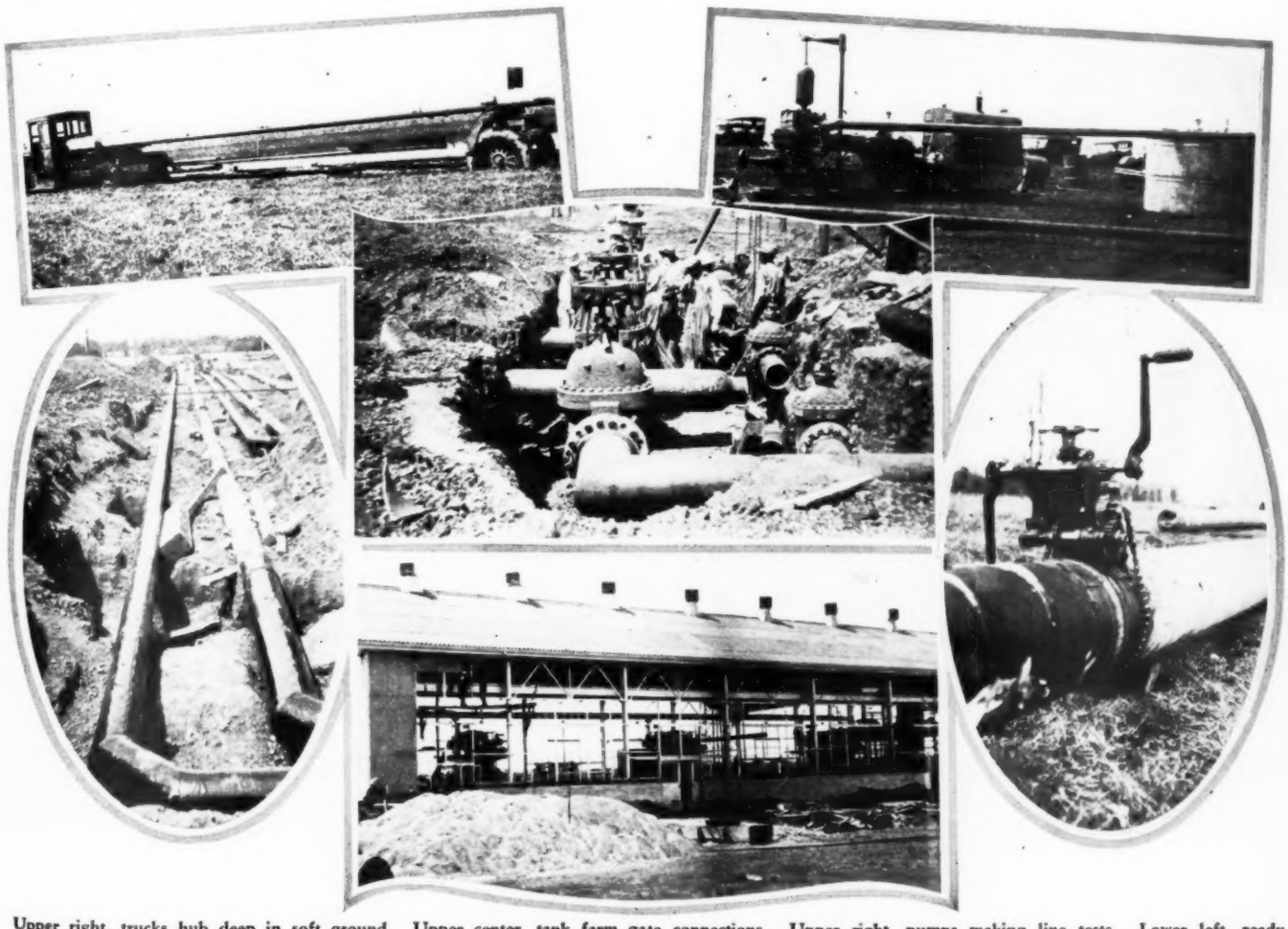
To protect the line against corrosion the pipe is both painted and wrapped. The first coat is Texaco Asphalt Primer. Following this is a hot application of Texaco No. 35 Asphalt, then a 15-pound saturated rag felt followed by another hot application of asphalt. The painting and spiral wrapping was done at the mill by machine by the Hill-Hubbell Co. Following the last coat of asphalt the pipe was wrapped with Kraft paper which kept it from sticking and made it easier to detect any damage to the corrosion protective coat during transit or construction. The paint was left off the ends and applied after welding the pipe into sections.

All of the main line stations have steel framework and red asbestos roofs. Five of the stations on the southern end have asbestos side walls and the remaining four are built with brick. Each station is designed to give ample light.

With one exception all of the stations are powered with 350-horsepower vertical Diesels, driving three 20,000-barrel reciprocating pumps. The engines were installed by MacIntosh and Seymour and Worthington Machinery Co. and the pumps by Wilson, Snyder and Prescott. The only electrical unit is at Scammon, Kan., and the motors there drive reciprocating pumps. There is an exception in the type of pumps at two stations; one has four 15,000-barrel units and another three 15,000-barrel units.

When the jointly-owned system was organized, the transporter purchased 57 miles of 10-inch running from Seminole to Cushing and a pump station at Lima which has a capacity of around 35,000 barrels daily.

While construction of the big line was in progress the company was building 131 miles of Victaulic coupled 8-inch from Hayworth station in Illinois to Lawrenceville, Ill., to supply refineries there. Extra heavy seamless pipe made by Spang, Chalfant & Co., Inc., was used and Henry L. Lemons was the contractor. This line will have an initial capacity of around 14,000 barrels and was protected against corrosion in the same manner as the big line.



Upper right, trucks hub deep in soft ground. Upper center, tank farm gate connections. Upper right, pumps making line tests. Lower left, ready for backfilling. Lower center, a typical main line station. Lower right, machine for cutting coupons to test welds.

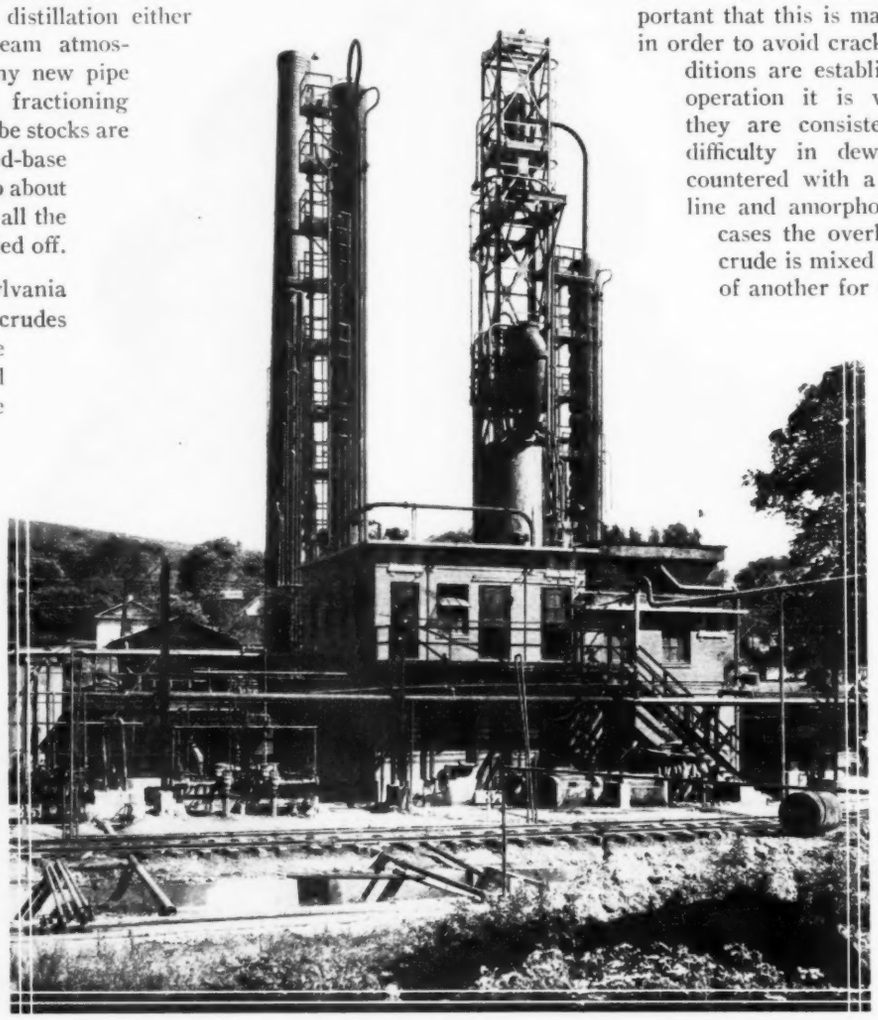
Refiners Are Installing New Equipment for

The Manufacture *of* Bright Stocks

By F. R. STALEY

THE prices for bright stocks have nearly doubled during the last fifteen months as a result of the enormous demand brought about by their more general use in blending the new oils for modern internal combustion engines. Consequently the refiner is studying and installing new equipment to increase yields of these valuable products. It has been shown that some mixed-based crudes containing considerable asphalt can be refined to produce overhead stocks of high quality. By the usual methods of refining it would not be economical to manufacture bright stocks from the reduced base of such crudes on account of the quantity of acid required and the large treating losses involved. Overhead stocks are made by single flash distillation either under vacuum or steam atmospheric pressure. Many new pipe stills equipped with fractioning towers for distilling lube stocks are being installed. Mixed-base crudes are run down to about 5 to 10% tar bottoms, all the lubricants being distilled off.

In case of Pennsylvania or Mid-continent crudes containing very little asphalt the standard procedure is to refine the base or residuum. It is necessary only to filter and dewax Pennsylvania stock, while the latter is treated and neutralized first. When contact filtration is used the filtering and neutralizing occurs simultaneously. These oils can be reduced to about 450 deg. F. flash and processed as a long residuum or reduced to 600 deg. F. fire test (flash from 520 to 540 deg. F.) and processed as a stock. In the latter case the lighter viscosity lubricants are taken overhead and refined separately as a neutral oil. Long residuum contains the entire lubricating content of the crude. Its use in blending motor oils appears to have certain advantages over the use of heavier stocks from the standpoints of quality and economy, however, the blender usually buys viscosity, and his most profitable selection will depend upon the relative costs of the two oils. In the case of a new plant less equipment is required to process a long residuum than for a stock and a neutral.



Installation of vacuum pipe still to manufacture overhead stocks. Photo by courtesy Smith Engineering Co.

In the distillation of overhead stocks considerable care must be taken in the design of the unit and in the operation in order to avoid difficulty in the subsequent filtering and dewaxing. In the case of steam atmospheric distillation, it is essential that the fractionating tower has sufficient capacity to permit the use of sufficient steam and then properly fractionate in order to prevent asphaltic substances being carried overhead in the distillate, since this would cause a blue cast very difficult to remove. In the case of vacuum distillation it is important that this is maintained at all times in order to avoid cracking. Once the conditions are established for the proper operation it is very important that they are consistently maintained or difficulty in dewaxing may be encountered with a mixture of crystalline and amorphous waxes. In some cases the overhead stock from one crude is mixed with a residual stock of another for acid treating and dewaxing. However, this is not necessary when the stock is properly distilled.

Chemical Treatment

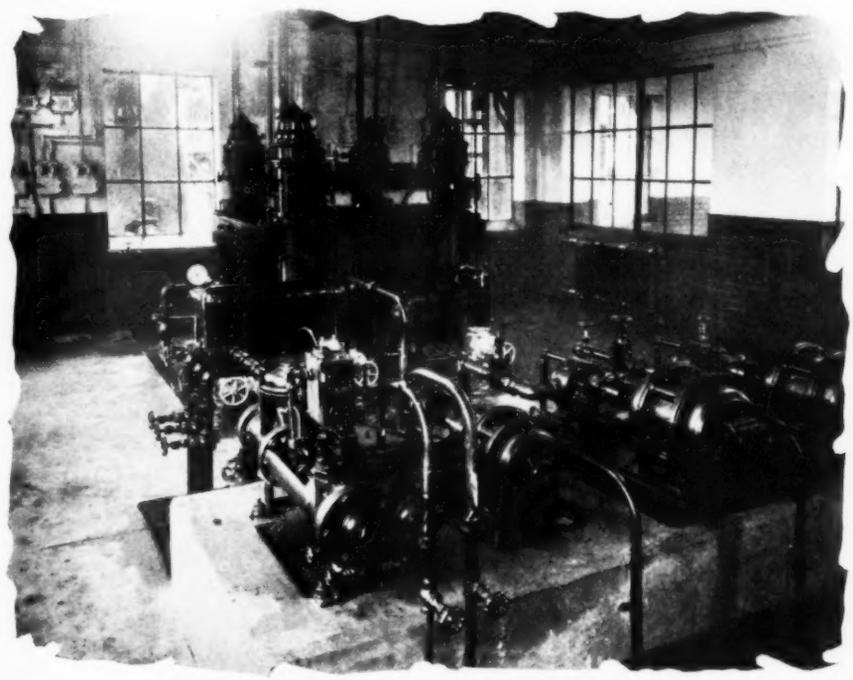
In order to stabilize the color and improve the cast it is necessary to acid treat an overhead stock. The average Mid-continent residual required from 25 to 50 pounds of sulphuric acid per barrel, either 93% or 98% being used, while an overhead stock will require considerably less, usually from 10 to 20 pounds per barrel. As a rule 98% acid will produce better color than 93% acid and a smaller quantity will be required. Lubricating stocks are usually treated in a batch agitator, but continuous and semi-continuous treating is being successfully used and in some cases the stock is treated in naphtha solution. When residual oils are treated batch the acid is usually applied in two successive dumps known as the cutter and the body. For the cutter the minimum quantity required to gather is used. The treating tem-

perature is important and best results are obtained by keeping it at a minimum maintaining the proper fluidity of the oil. Air is usually used for agitation. Tests using inert and combustible gas do not show any better color than air agitation. After acid treatment the oil is settled to remove pepper or fine sludge or run through centrifuge machines to remove all traces of suspended matter. A system of continuous treating in which streams of oil and acid are fed through a battery of centrifuges and the sludge removed by centrifugal force as it is formed is being studied by some refiners. After treating the oil is neutralized either with soda or lime or with clay. For acid treated stocks contact filtration has decided advantages.

Control instruments for vacuum pipe still.

Dewaxing

In general the problem of dewaxing an overhead stock is similar to that for residual oils. The waxes occurring in the low boiling point fractions have a tendency to form crystals, the lighter the fractions the larger the crystals. The heavier waxes are amorphous or when crystalline form very much smaller crystals. The centrifuge is very efficient in removing the heavier or higher boiling point waxes or a mixture of the lighter and heavier waxes occurring in long residuum. For dewaxing low viscosity oils or wax distillate the wax press is used for crystallic wax and the filter press with a filter aid is used for a mixture of crystalline and amorphous wax. A stock must be dewaxed in naphtha solution. The cold test on the dewaxed oil depends upon the percentage and gravity of the naphtha and the chilling temperature. For zero pour point, stocks about 70% to 80% of naphtha is used in the solution and it is chilled to minus 35 to 45 deg. F. using direct expansion. Solvents other than naphtha are more efficient in wax removal, less refrigeration being required. However, evaporation losses are more expensive due to the higher price of the solvent. It is usually necessary to treat and filter an overhead stock before dewaxing it in the centrifuge in order to remove such compounds that would prevent precipitation of the wax duri· g chilling.



Pumproom of vacuum unit; vacuum pumps shown in rear.

Properties of Overhead Stocks

The color of finished overhead oils is usually lighter than that of residual oils, and the carbon residue is considerably lower. The gravity and the viscosity temperature coefficient will depend almost entirely upon the crude. It is not possible to change the viscosity temperature relation by vacuum distillation. This property is characteristic of the types of hydrocarbon molecules present, and their structure is not changed by distillation which only effects a separation. The flash test on a vacuum distilled and fractionated stock is higher for a given viscosity than for a steam atmospheric distilled stock due to the more complete removal or fractionation of the lighter constituents. In conclusion it might be stated that the refining industry is making every effort to increase yields and improve the quality of the various grades of bright stocks. Improved methods of distillation, chemical treatment, filtration and dewaxing are being used. Vacuum distillation enables the refiner to produce bright stocks from other than green crudes which should materially increase the supply. The selection of the best combination of processes and equipment for the manufacture of bright stocks depends to a large extent upon the type or grade of crude oil to be refined. The details of the process should be worked out in a semi-plant installation. At the present time many of the engineering companies building refineries and refinery equipment have experimental plants and data which enables them to build plants that will produce the highest quality product most economically from a given crude oil.

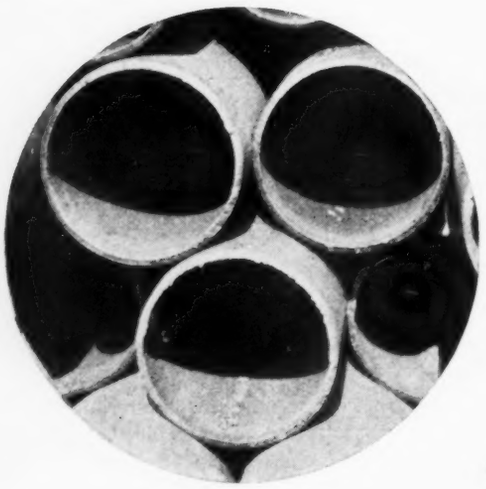
Making New Pipe Lines Out of Old

At left—Automatic acetylene cutting machine cutting screw coupling off 8-inch screw line. An example (below) of the type of cuts made by the machine.

RIPPING up an old 8-inch screw line for pipe to weld into 40-foot joints for a main line system and cutting the old screw couplings off at a very low cost, featured the construction of the Oklahoma Pipe Line Co.'s line from Cushing to the Oklahoma City field, a distance of 51 miles.

The old line taken up was one of the double 8-inch screw lines running from Drumright to Burbank, Oklahoma. This line had approximately 20 miles of loop work in it and only one 8-inch was necessary to care for the present load. [About 15 miles of the line had been taken up with a tong gang early in the spring but with the decision to build into the capital city pool and use the old 8-inch pipe, the division officials decided to cut the couplings off with acetylene machines.]

It was found that two welders, each with a helper, could cut 90 joints daily. The fastest time made in cutting a coupling was three and a half minutes. The record made in cutting the coupling was when 300 joints were cut in one day. This required three welders with machines and helpers, and one welder and helper with a hand torch.



Right — The firing line finds it easy going through this particular flat section. Otherwise the line traversed some hilly and rough country.

Upper picture—Group of welders in the pipe yards welding the random length joints into average 40-foot joints. Each welder has a helper to make his work progress faster. Directly below is a construction gang making an overbend.

How an Old Screw Line of 20 Foot Joints Was Converted Into a Welded Main Line to Serve the Oklahoma City Field

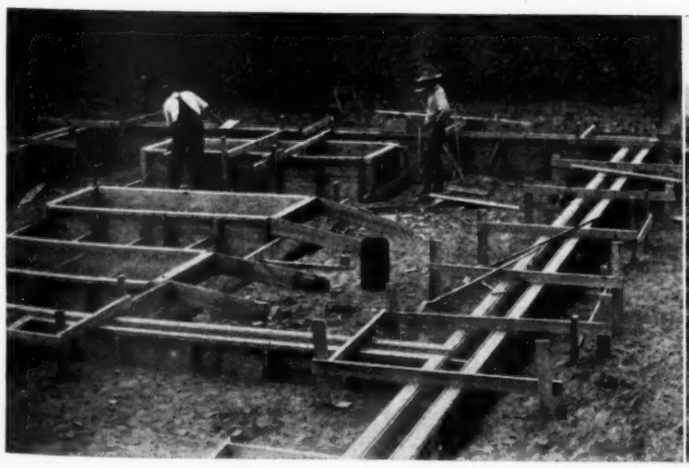
The cuts were uniform throughout and a clean 60-degree angle cut was made on either side of the coupling leaving the pipe with a good bevel edge for welding.

After the pipe had been cut out of the line, it was shipped to Drumright where a crew of welders welded it into joints with an average length of 40 feet. When the demands for pipe grew heavier, the short joints were shipped direct to some shipping point along the line and welded into 40-foot joints on the ground where the cars were unloaded.

In all, approximately 70 miles of pipe was taken up and for the most part it was in good condition. Fifteen miles of it had been buried 12 years and the remainder had been underground for 8 years. In the yards at Drumright the pipe was graded before being welded into the long joints. When it was necessary to ship the short joints to shipping points, pipe was also graded before loading.

After a section of completed line was tied in, the cleaning machines were put to work and after they had passed over a joint, another inspection was made to make sure no faulty joints were getting in the line. Whenever such joints were found, they were repaired if practicable, or cut out and other joints welded in. Before burying the reconditioned pipe, it was coated with paint to protect it from corrosion.

Badly pitted spot (upper right) found after cleaning. Above, welder strengthening weak place with a spot weld. Right center is a completed cut beneath one of the several railroad crossings which were all cased.



Pipe cleaning machine (left center) idling while crew jacks up a field gathering line to permit the machine to proceed. Concrete foundation forms (lower left) for the centrifugal pump station near the field, and tank builders (lower right) building tankage.

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Many Objectionable Features Eliminated by Proper

Refinery Pollution Control

By W. C. SMITH, *Engineer, Texas-Pacific Coal & Oil Co. and Transcontinental Oil Co.*

WITHIN the last three years oil refineries and their capacity have increased by leaps and bounds until they have become one of the greatest industries of the Southwest, bringing untold wealth with their development in the sections of country where they are in operation.

The waste and lax methods of operation in vogue a few years past have been turned into an economic asset. A complete refinery making gasoline and other by-products with a five-thousand-barrel capacity under the old system ordinarily would require the employment of about three hundred men; whereas, under improved methods, twelve per cent in labor alone is saved.

By the use of traps properly located and constructed around loading racks and on drainage outlets, as much as fifty barrels of oil per day is salvaged, which can be either used as fuel, or again refined. These items alone amounts to several thousands of dollars per annum. The accompanying illustrations show properly designed loading racks and traps, as well as those not so well designed. A loading rack well constructed and drained reduces fire hazards to a minimum.

In the use of contact methods of decolorizing lubricating stock, which is a very expensive method to use, eighty-five per cent of the deteriorated clay can be restored to usefulness by proper reburning, thus preventing the unsightly mass from being dumped into the drainage ditch and polluting the streams below the refinery.

By employing modern refinery methods, even the ever despised heavy oil sludge is utilized: the acid is extracted and used in cooking the contact clay and the residue of the sludge is blended with fuel oil to make a very good fuel, thus eliminating what formerly was a real nuisance.

It would require too much space to go into detail as to different methods which have been the means of building up the refinery business to its present high standards; but one does not have to draw on imagination to see what a saving has been wrought by the adoption of scientific methods. By simple mathematics it can be seen that many thousands of dollars are saved each year, to say nothing of the splendid morale that is built up among the employees by virtue of nice, clean environments in which to labor. A group of contented employees will do a third more work with less effort and with greater efficiency. A well-kept refinery has the same effect on men who work at a plant that a well-designed and clean house and yard have upon a lady of the household. By virtues of such environments they have a higher conception of life and will lend their very best energy to the plant for which they labor. So it is with outsiders who may visit the refinery or pass along the highway beside it, a message of good will is carried away with each visit which in every instance means added sales to the output of the refinery.

With the advent of scientific methods there can be no doubt but that waste can now be turned into an asset and our refineries all be placed upon a high standard, and one which the most exacting community will be proud to have in its midst.

Picture No. 1—A well-designed loading rack. Picture No. 2—Loading rack improperly constructed. Picture No. 4—A drainage trap for salvaging waste oil. Picture No. 3—Oil waste where no trap is provided.

Another feature that cannot be overlooked is the injurious effect of waste passing down open drainage courses and through premises of individuals below the plant. Such property owners feel, and rightly so, that their inherent rights have been trampled underfoot and in many instances are able to establish their claim, which sometimes proves very expensive to operators of refineries and causes a sentiment to develop in the community against such institutions. This may be overcome by using improved methods and showing proper consideration to such owners and the general public.

85-170 B.H.P. ENGINE COMPRESSOR

BUILT AS SINGLE OR TWIN UNIT

TYPE 80

ALTHOUGH existing types of Cooper-Bessemer engine compressors are performing in a manner thoroughly satisfactory to owners and operators, Cooper-Bessemer engineers are constantly seeking ways to make these units still better. ~ Out of scientific research, laboratory tests, advanced engineering, modern equipment and materials, has been developed a new and improved Type-80—an engine compressor that offers even greater value than the models preceding it. ~ Some of the refinements found in the new Cooper-Bessemer Type-80 are: a new and better breather compartment; special heat-resisting exhaust valves; longer power cylinder liners; larger inlet valves; improved exhaust chambers; better water cooling throughout, and more efficient compressor cylinder valves.

MANY IMPROVEMENTS IN NEW MODEL

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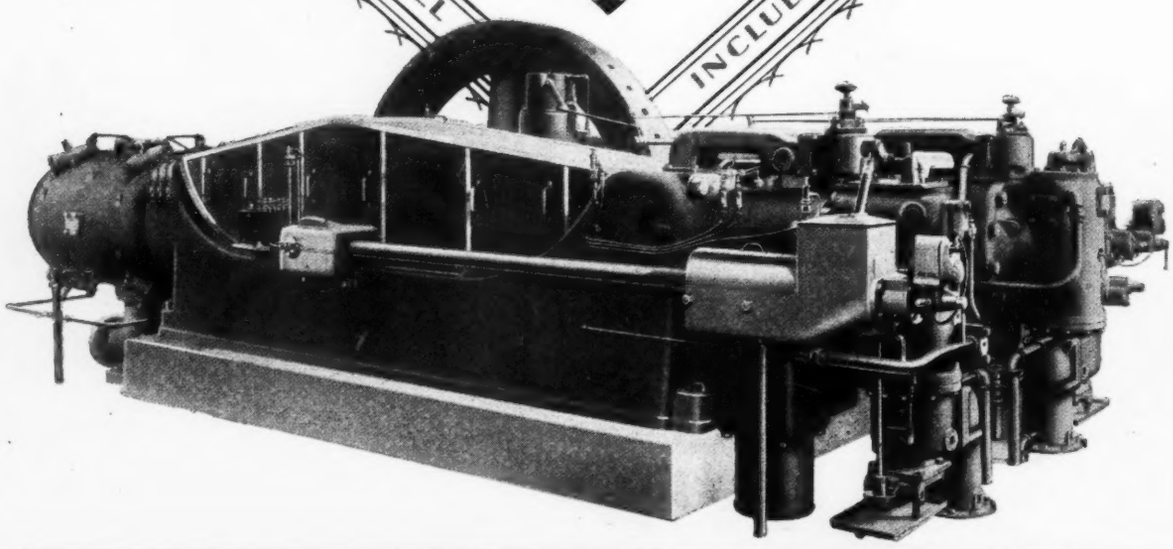
The New Type-80 is looked upon as simply a larger Cooper-Bessemer built smaller—with every detail cared for to insure lasting, economical and dependable operation. ~ It is the 4-cycle, horizontal, direct-drive type, built as a single cylinder—85 B.H.P., and as a twin cylinder—170 B.H.P. ~ Its chief applications are air and gas lift, gas boosting, gasoline extraction from gas, gas compressing, handling still vapors and weathering gases in refineries, air compressing, and repressuring oil sands. ~ *Write for Bulletin entitled—*

"THE NEW AND IMPROVED TYPE-80 COOPER-BESSEMER GAS ENGINE COMPRESSOR."



THE COOPER-BESSEMER CORPORATION

50-60 B.H.P. ENGINE COMPRESSOR

CONVERTIBLE GAS OR OIL ENGINE

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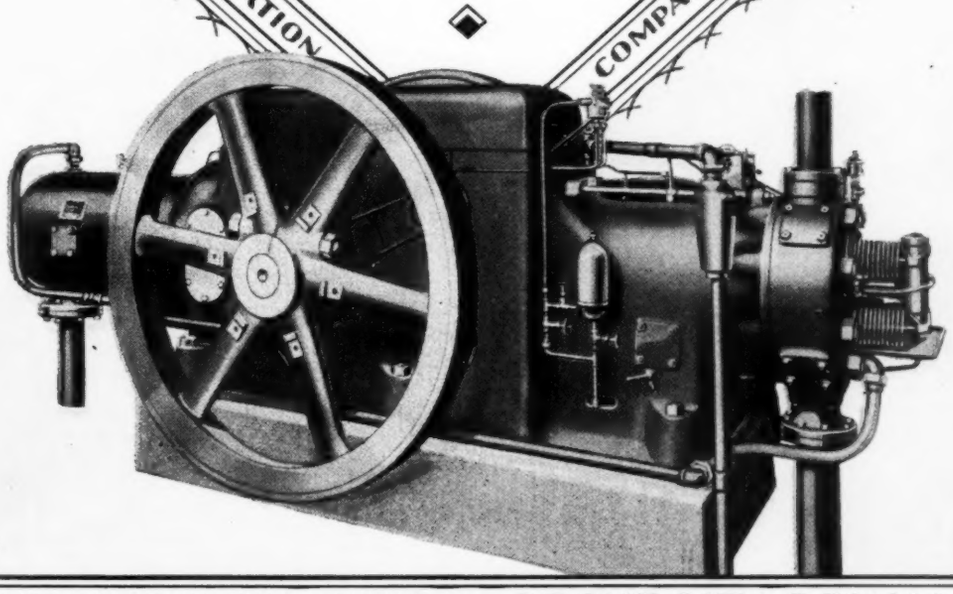
The first Cooper-Bessemer Type-16 engine compressor units built have been in use over two years. With the exception of a few changes and refinements which were found necessary, these units have been practically free from trouble. Type-16 is small, compact, self-contained—the engine and compressor being built into one direct-drive unit. It is rated at 50-60 B. H. P., depending upon the speed. The unit is shipped completely assembled, and is readily convertible for either gas or diesel operation. Using single or two-stage compressor cylinders, its range is from 26 inches of mercury vacuum suction to 2000 pounds discharge pressure.

Type-16 has the fuel economy inherent in 4-cycle engines; its semi-automatic operation effects a material saving on labor; rugged parts and solid construction reduce maintenance costs; and the consumption of lubricating oil is low.

Within its power rating, its applications are the same as for Type-80, plus belt-driving power equipment. *Write for Bulletin entitled*—"COOPER-BESSEMER TYPE-16 COMPRESSOR UNIT."

PRACTICALLY TROUBLE-FREE OPERATION

COMPACT BECAUSE DIRECT-CONNECTED



MT. VERNON, OHIO & GROVE CITY, PENNA.

Modern Methods in
Pipe Line Construction*

By ELMER F. SCHMIDT,
General Superintendent Lone Star Gas Co.

A NEW standard of pipe line construction has come about during the past few years. Pine line projects are now possible that only a few years ago could not have been economically accomplished. It is unquestionably true that the wide expansion of natural gas lines now under construction and proposed will bring prosperity and industrial development to communities far removed from gas fields.

These projects have been made possible mainly by the very great improvement that has taken place in construction methods and equipment which brought about the reduction of cost of large lines and reduced greatly the time required to complete them.

Many new factors enter into the building of large lines beginning with the preliminary survey to the final testing of the finished line. The most modern means of transportation, the airplane, and highly developed telescopic photography has been brought into modern pipe line construction. In some of the rugged sections of the country it has been found practical and essential to make aerial surveys of the proposed route. By this means a reduction of the time required for the preliminary survey is accomplished and an opportunity is afforded for the selection of the most advantageous route. An aerial survey to include a strip four miles wide along the proposed location can quickly be made and will disclose most of the obstacles that would confront the construction work. With such a survey at hand it is possible at once to stake the best right of way particularly in rough and mountainous country. The airplane is also used by some contractors for inspection of the proposed route, making it necessary for more close inspection only where rock may be encountered or unusual construction difficulties exist.

Following the survey the right of way is purchased and then the first step in the actual construction begins. Clearing the right of way immediately follows its purchase. Gates are built in fences, bridges constructed across creeks and timber cut so that stringing of the pipe may proceed.

At the railroad siding the pipe is unloaded from the cars directly to trucks (See Illustration). This is accomplished by the use of a gin truck which is a truck with gin pole mounted on the rear. This gin pole has a long extension reaching over the truck to be loaded and to the railroad car

*Presented before the Atlantic City meeting of the American Gas Association.

Scenes of modern gas line construction.

and is fitted with blocks, cable, and winch for lifting the pipe. Two men on the car place hooks in each end of a joint of pipe and the winch on the truck lifts the pipe from the car and places it in the truck where two men unfasten the hooks and the same procedure is repeated until the truck is loaded. Thus with five men, one of which is the driver of the stringing truck, more pipe can be unloaded from cars, much more rapidly and safely and with less damage to ends of pipe than with the old gin pole method with team or tractor.

Stringing of the pipe can now be accomplished with large trucks even in rough territory by the use of caterpillar tractors to help in places where the trucks cannot move by their own power. Steep inclines, mud, small creeks and many other obstacles that could not be traversed by trucks are now overcome with the additional help of the caterpillar tractor. Much time is saved and consequently expense where this can be done.

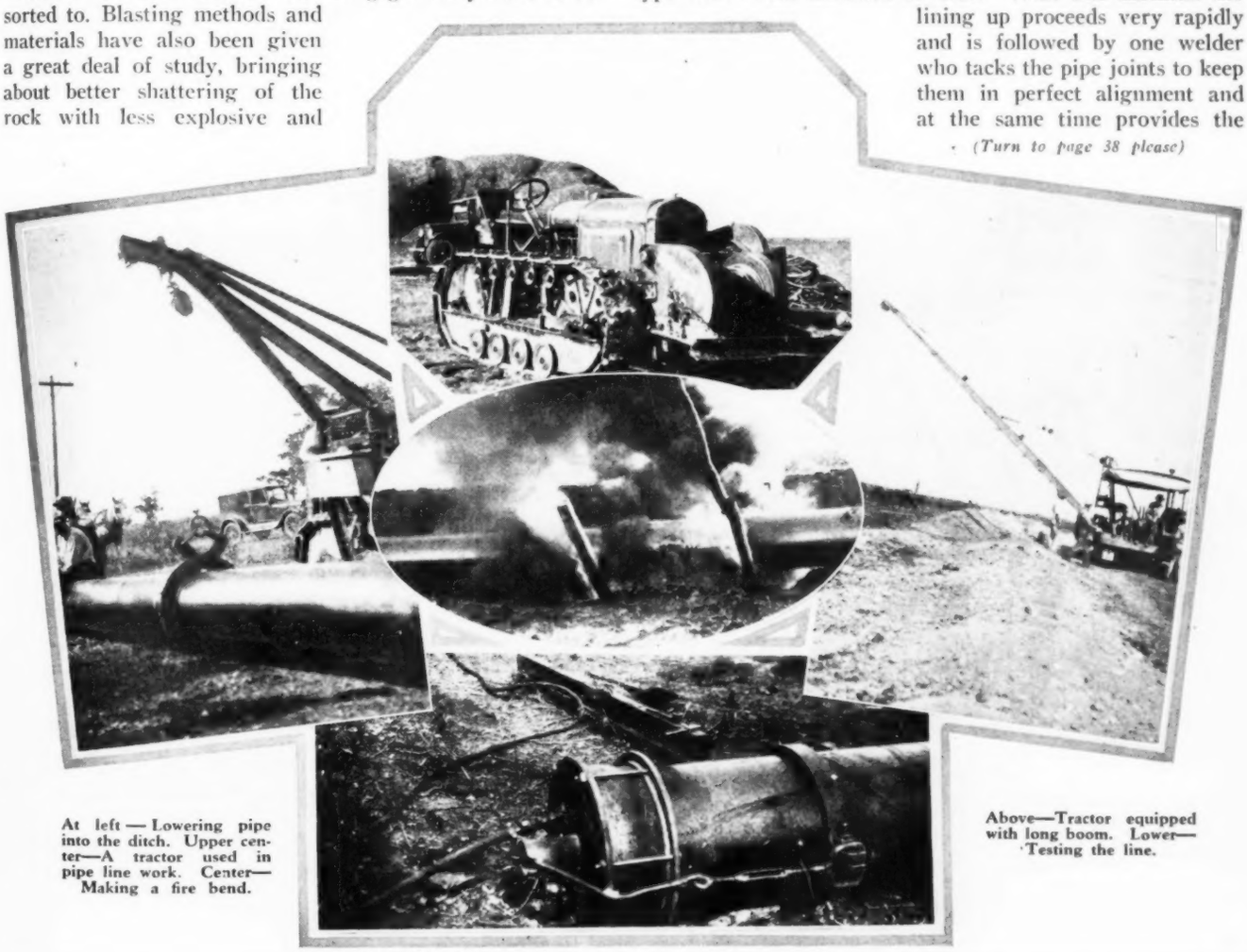
Ditching machines have gradually been improved until they are now capable of doing considerably more work than formerly (See Illustration). They are made much more sturdy for main line work, weak places have been strengthened and improved steels and alloys are used in wearing parts, giving them practically an indefinite life where formerly these parts required replacing very often, resulting in expensive delays and shutdown time. It is now usually customary to run ditching machines twenty-four hours each day on long pipe line projects, keeping open ditch for the laying crew.

Elmer F. Schmidt

Where rock is encountered, blasting generally must be resorted to. Blasting methods and materials have also been given a great deal of study, bringing about better shattering of the rock with less explosive and holes spaced further apart than formerly. Experience has taught these experts that different rock formation requires different treatment to accomplish best results. With competent workmen in this line, and with the use of portable air compressors for drilling the holes in the rock, much time and expense can be saved. It is possible to blast rock so that a ditching machine can remove the rock without unusual wear to the machine. A machine now used generally on this work is a shovel type pull stroke operated ditcher (See Illustration). This machine is similar to a steam shovel often used on sewer work, but is operated with a powerful gasoline engine. It will replace large numbers of men in rock work and is a big money-maker where considerable rock is encountered. It is also very useful in making right of way for ditching machine in rolling and rough country and in making approaches for river and creek crossings.

In gas welded line construction as soon as the stringing is started the pipe is lined up on skids or dollies, five or nine joints in a line, and tacked in line for the roll welders or firing line. The number of joints lined up is controlled by the contour of the country and the welding crew. Since each generator wagon supplies gas for four welders, one wagon is used where five joints are welded together and two wagons in the case of nine joints. The pipe is lifted and placed on these skids by the use of a tractor equipped with pipe laying boom and hoist, which is one of the best time and labor-saving devices on the job (See Illustration). This machine is of the crawler type with boom mounted on side. With this machine the lining up proceeds very rapidly and is followed by one welder who tacks the pipe joints to keep them in perfect alignment and at the same time provides the

(Turn to page 38 please)



At left — Lowering pipe into the ditch. Upper center—A tractor used in pipe line work. Center—Making a fire bend.

Above—Tractor equipped with long boom. Lower—Testing the line.

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proper spacing between joints which is held by the tacking.

As soon as the lining up and tacking is started the firing line welders begin operations. A firing line crew is composed of four welders for five joints, or eight welders for nine joints, a generator man, one welder helper and a water wagon and driver. An extra welder is used for relieving the regular welders, where three or more crews are used. The helper distributes welding rod sufficient for each weld before the welding is started and rolls the pipe with tongs as the welding progresses. The equipment consists of a 100-pound acetylene generator for each four welders, mounted on a wagon which also has racks for eight oxygen bottles, a supply of welding rod, carbide, drinking water bucket and tools (See Illustration). The necessary oxygen and acetylene regulators, welding hose and torches are also included. The wagon is attended by a generator man who manipulates the oxygen bottles and operates the acetylene generator. The water wagon, for hauling and supplying water for the generator, is provided with water tank and hand pump. These welders make roll welds joining five or nine joints of pipe into one string. The pipe is rolled and the welding is done practically on the top of the pipe, until the entire girth weld is completed. The number of these welding units required is determined by the rapidity with which it is desired to build the line. As these firing line welders finish a section they advance to another section already prepared for them by the lining up crew and the tack welder.

The testing crew now fastens suitable air-tight caps to each end of these long sections (See Illustration). These caps are provided with connections for pumping air into the pipe to 50 pounds gauge pressure, which is provided by a portable air compressor. After 50 pounds pressure has been reached soap suds are applied to each girth weld and factory seam, and if leaks are found they are repaired. Seldom are leaks afterward developed in the girth welds at higher pressures that are not discovered by this method. The compressed air is drained from one section to the next until the pressure equalizes, saving time and expense in running the compressor. All the welds, with exception of the tie-in welds, are thus tested above the ground, assuring a tight line when completed.

These sections are now rolled over the ditch and placed on skids with the use of winch tractors. The tractors are of the caterpillar type and with the winch are very powerful machines (See Illustration). They can move long sections of large diameter pipe with great ease and precision in either horizontal or longitudinal direction. With the assistance of boom and stiff leg tractor they line the pipe up ready for the tie-in or bell hole welds. These welds are called bell hole welds because a small bell hole is required so that the welder can get under the pipe to make the weld. The pipe is held above the ditch with skids reducing the size of bell hole required. This is the only weld made where the pipe cannot be rolled. These sections welded together make a continuous welded line from the starting point.

In moving the pipe after welding it is good practice to handle it rather roughly, in order to put as much strain in the welds as possible, which should break any poor welds that may have been made. These welds are made having a greater tensile strength than the pipe itself, if proper material is used and experienced welders are employed, and will rarely break. Each weld is marked so that the welder who made the weld may be known in the case of a failure.

The necessary bends to make the pipe conform to the bottom of the ditch are made in these sections sometimes before the tie-in welds are made and often afterward (See Illustration). The same methods cannot be used for bending large pipe of high or low carbon content, but either can be successfully bent by a skillful operator, without the least wrinkling or buckling of the pipe. The very best and most economical material to use for fuel for fire bending has been found to be discarded automobile casing rings. These are cut from junk tires by dealers from the inside rings of the casing. They can be placed in the ditch for any length to give a gradual sag bend or they can be hung over crotch skids on top of the pipe for an overbend. They are wire inserted and consequently will remain on the skids until burnt out, giving a concentrated heat where desired. Their particular advantage comes from their cheapness and the extremely hot and quick fire which they produce, reducing the cost and time required to make bends over other material.

It is necessary to place slack in the line in order to keep the line under compression as much as possible, even with a drop in temperature, from that at the time the line is laid. This is accomplished by placing the pipe on slack skids approximately 500 or 600 feet apart and allowing the pipe to go down to the bottom of the ditch between these skids. These loops of slack are provided progressively with the tie-in welding and material for the slack is obtained from the loose end ahead. The lowered sections are then backfilled in order to prevent the slack from moving ahead. Early in the morning when the temperature is at the lowest point, and the pipe therefore at its shortest length, these skids are pulled out by lifting the exposed pipe with a boom tractor, equipped with an adjustable stiff leg (See Illustration), and the pipe is crowded into the ditch. With the stiff leg this machine is capable of lifting 50,000 pounds. If the proper amount of slack has been provided the pipe will almost rest on the bottom and best results are obtained if surplus slack is provided requiring the pipe to be forced into the trench. This helps to assure that the pipe will still be under compression at any lower temperature.

The backfilling is done with a backfilling drag line machine (See Illustration), which is operated by two men who can fill over a mile of ditch for large pipe in a 10-hour day. One operator moves the machine forward while the other operates the drag line. In the hands of competent operators the mound is left even and all of the dirt thrown out by the ditching machine is back on the line. The bell hole welds are left open for inspection when full line pressure test is made.

In order to blow each section between gate valves and free the line from dirt accumulated during the construction, a rubber joint sleeve is provided on the inlet side of each gate valve. The line is raised and blown without damaging the gate valve. As soon as the section is cleaned, and at the same time purged of air, the pipe is lowered and the full line pressure or maximum working pressure applied. The section is tested for leakage by the Bureau of Mines shut in pressure method, using dead weight pressure gauges and accurate thermometers at each end of the section.

Highway and railroad crossing are cased with corrugated culvert pipe of larger diameter than the line in advance of the laying crew. Welded sections of pipe which have been tested for leaks are pulled through the culvert pipe with a winch and welded to the preceding section as the laying progresses.

Pipe line protection is applied immediately after the roll weld tests are made in the case of cold applications and just before the lowering in when a hot application is used.

Another factor that is contributing to lower pipe line construction costs is the physical examination of all men employed in such work. On most construction jobs it is required that each man pass a physical examination conducted by a physician. The physician is employed by us and is stationed on the job. About 25 per cent of the applicants fail.

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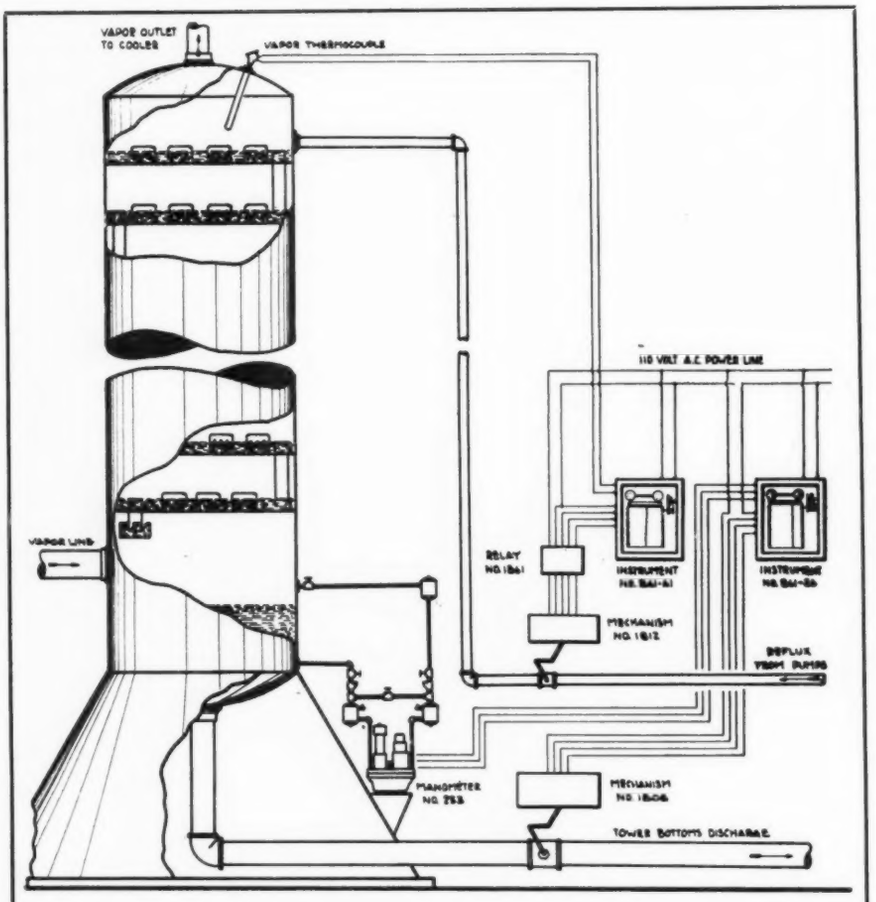
Control *of* Refinery Operations With Instruments*

By F. M. POOLE[1]

THIS subject, "Instrument Control of Operations in the Refinery," is one that, a few years ago, would have started an argument. It was not so long ago that instruments were looked upon somewhat unfavorably and as not being essential. Now we may still have the argument, but it is rather on what kind of instrument the refiner shall use than shall he use any instruments at all.



TOWER TEMPERATURE AND LIQUID LEVEL AUTOMATIC CONTROL
BROWN INSTRUMENT COMPANY
PHILADELPHIA, PA.
F.M.POOLE DISTRICT MANAGER
KANSAS CITY ST. LOUIS TULSA
W.D. WOLFE

In your past meetings you have had papers read giving a resume and growth of instruments as applied to refineries. These papers, while serving to emphasize instrument importance — and that they are oftentimes the difference between a profitable and an unprofitable operation — have not been regarded as being particularly tangible or helpful to the everyday problems. I dare say the refiner has certain questions in mind he would like to ask; questions that have never been squarely met in discussions heretofore: For example, "Why should this particular type of instrument be used?"—or, "What can be done to better my installation?"

In today's discussion I want to be limited to two particular aspects of this subject and to go into them sufficiently that there will be some concrete, tangible benefit derived from them by the refiner.

If the refiner could know where he could get a complete and practical exposition of the merits and limitations of the several types of instruments offered, he would then feel more certain that he had acted to the best interests of his company in selecting this or that type of instrument for an application. He could feel more satisfied with his own judgment. Again, I imagine he would feel some elation if he had a little better knowledge of what instruments are capable of doing, which instruments are increasing in usefulness, and what additional work can be expected from them in the future. It is these two aspects I want to touch upon in this paper.

From its extended use today, one may assume the pyrometer is perhaps the most important of the temperature instruments. A pyrometer, whether for oil temperatures, tower, or furnace, is usually selected for its (a) sensitivity, (b) remoteness of operation, (c) capacity of recording several related temperatures on one chart. Pyrometers, as used today, usually operate on one of two principles—the millivoltmeter or the potentiometer. One of the most pertinent questions is, "Which is the better for my work in a refinery?"

For example, some, having in mind a comparison of the basic principles and the ultimate laboratory accuracy of each, may have asked themselves, "Can I not utilize this superior potentiometer principle in the instrument my operators use and get desirable operating characteristics?" This is a question on which there is a difference of opinion. Some believe you can. Others feel that it is better to use the potentiometer in its simplest form, in which its accuracy is not sacrificed to ruggedness—namely, as a portable standard, to establish the correct value of the initial point and then to use the simple millivoltmeter—from which more desirable operating conditions can be attained. However,

(Turn to Page 43, Please)

*Presented before the Manufacturers Committee Western Petroleum Refiners Assn., Tulsa, Okla.

1 Brown Instrument Co.

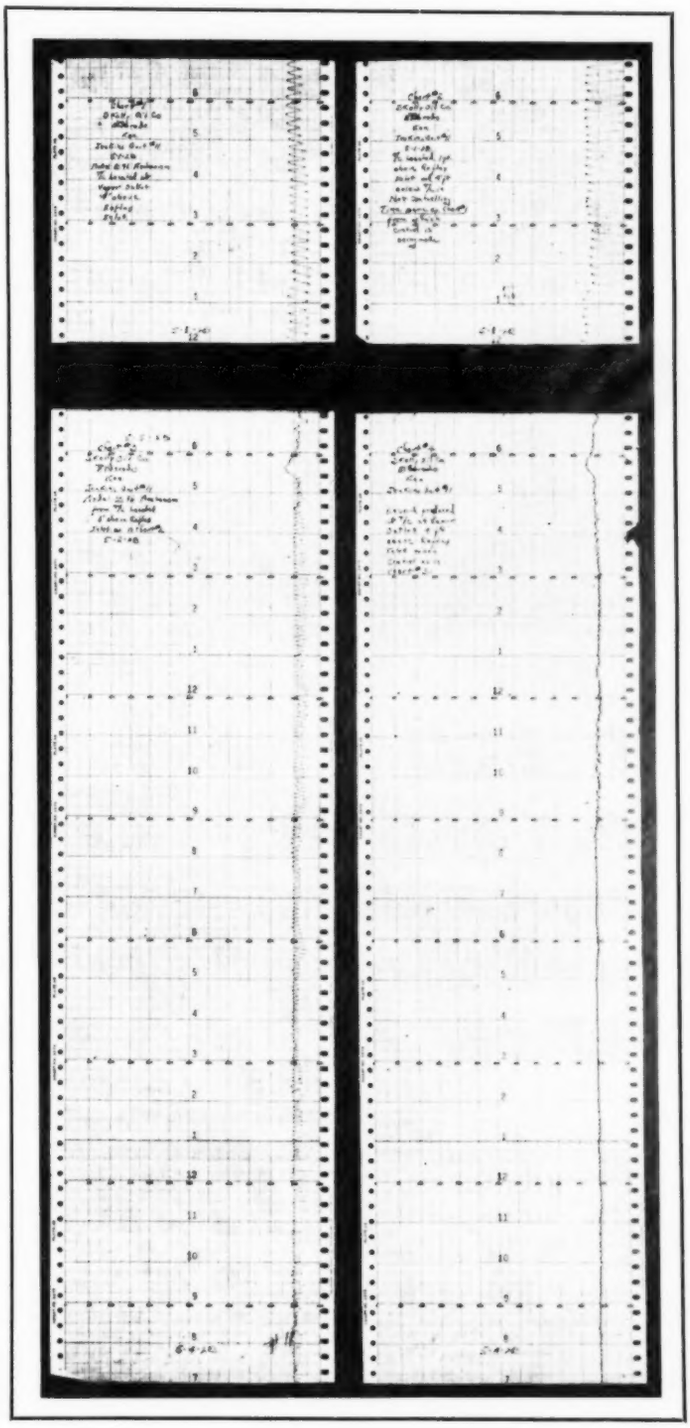
it would seem in order to compare specifically the merits and limitations of the two.

Earlier in the discussion I stated that sensitivity was one of the fundamental reasons why pyrometers have been selected in preference to other types of instruments. Sensitivity here can be interpreted to mean ability of the instrument to respond immediately to changes in thermal potential and to record them emphatically, with minimum time lag, so that the operator can make use of the information. The galvanometer is the heart of either pyrometer and that part which detects thermal potential changes. While the laboratory potentiometer can be built with almost any desired galvanometer sensitivity, the galvanometer sensitivity of the industrial potentiometer—particularly in the recorder—has, for reasons of design, a much greater limitation than the millivoltmeter galvanometer. Therefore, as the millivoltmeter galvanometer is more sensitive than the potentiometer, its record will represent a truer picture of the temperature trend and what took place. This is further true, inasmuch as temperature changes always mean record fluctuations on the millivoltmeter chart; the sensitivity of the galvanometer is not a matter of critical mechanical adjustment. Temperature trend, therefore, results from temperature changes.

Temperature trend is rapidly becoming to be classed just as important, if not more important, than extreme accuracy. This is apparent when one realizes the operator guides his unit as much from the temperature trend as from the actual temperature.

In remoteness of operation, either the potentiometer or the millivoltmeter can be regarded as satisfactory. The effect distance has on the potentiometer is to make its galvanometer even less sensitive due to the fact that the current value is decreased for a given unbalanced condition, which is the condition when there is a temperature change. In the millivoltmeter, the effect of distance, resulting from radical differences in lead lengths, is balanced out by internal resistance units which are adjusted once for any given installation. Variations from these lengths, arising from rewiring or relocating thermocouples, have no practical effect due to the high internal resistance used in the instrument. Radical lead length changes have no permanent effect on the galvanometer sensitivity, inasmuch as it merely means a balancing of the internal with the external resistance. However, either instrument can produce satisfactory records at a distance.

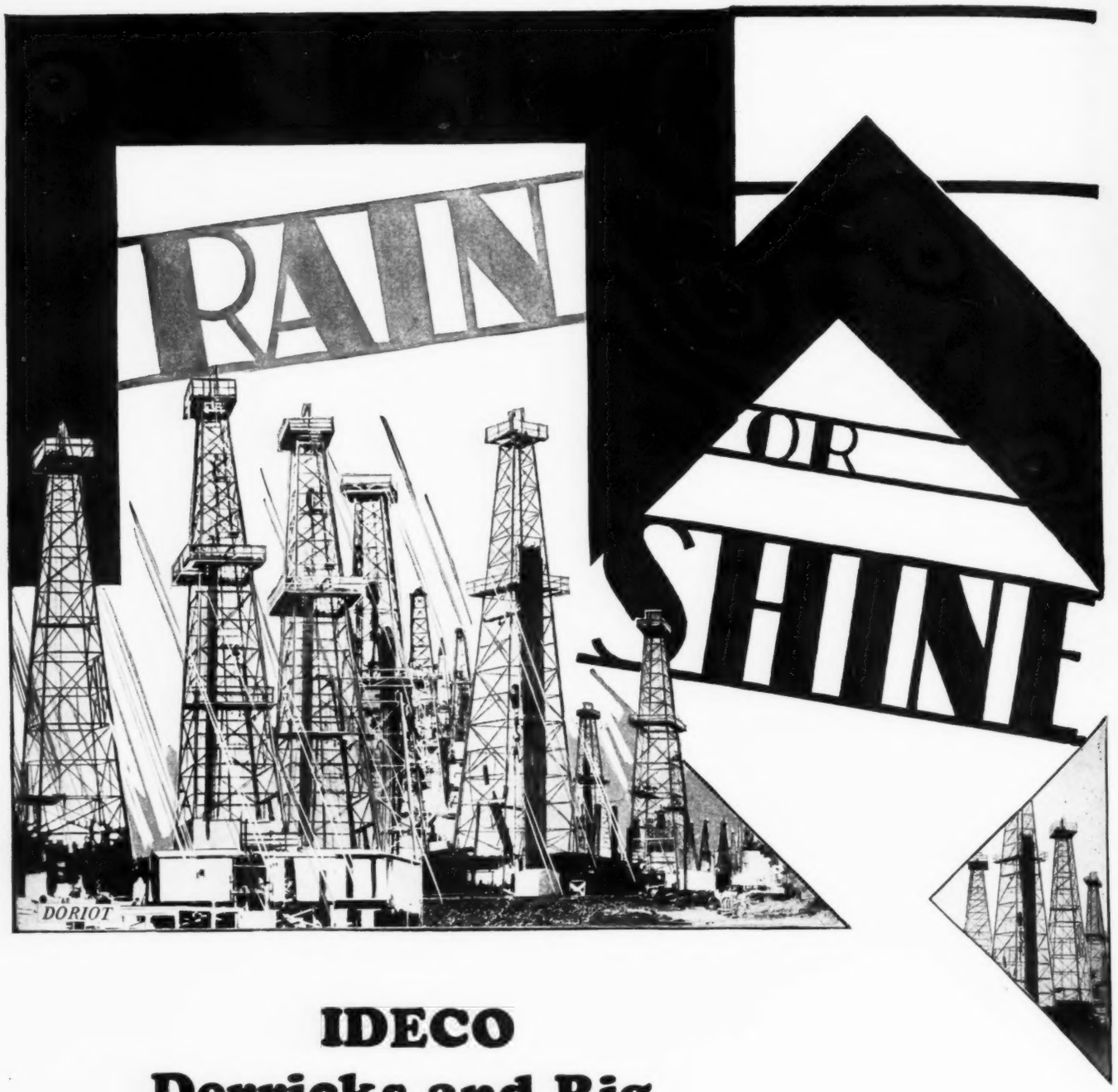
In making multi-record instruments for refinery use, the limiting factor is the time cycle. This is obvious when you consider the operator follows the trend of the temperature as much as the actual value. In this respect the millivoltmeter has the advantage; it is direct-acting in producing its record and therefore requires a minimum time to function. The potentiometer must go through several intermediate steps and, therefore, requires considerably more time to function. The comparison would run, say on a four-point instrument, about one minute on the millivoltmeter to about three and one-half to four minutes on the potentiometer; roughly, the millivoltmeter is about 3½ times as fast in its time cycle. It is apparent that this is a definite factor in determining how many records you can afford to have on one chart — regardless of how related they are and how nice it would be to have them so recorded. This time cycle requirement has an even more important bearing in adapting instruments to do automatic control work, as will be discussed later.



In oil temperature thermocouples, particularly on cracking stills where coke is present, it is important that the area inside the tube in contact with the oil be materially greater than the area exposed to the outside air. It has been found that if about 80 per cent of the total area of the thermocouple well, head and extension is inside the tube, your heat input into the thermocouple will still be greater — even after coke covers the well — than the heat dissipation into the air. This means that the conduction error remains negligible and there is no perceptible falling off of temperature as the coke builds up on the thermocouple well. I have observed a Cross unit oil temperature thermocouple which previously had a drop of 30° due to coke building up, drop only 5° F. with a thermocouple so designed.

In tower temperature thermocouples it is important that the thermocouple be located as near as possible—without being directly in it—to the point where the reflux mixes with the upcoming vapors from the

(Turn to page 46 please)



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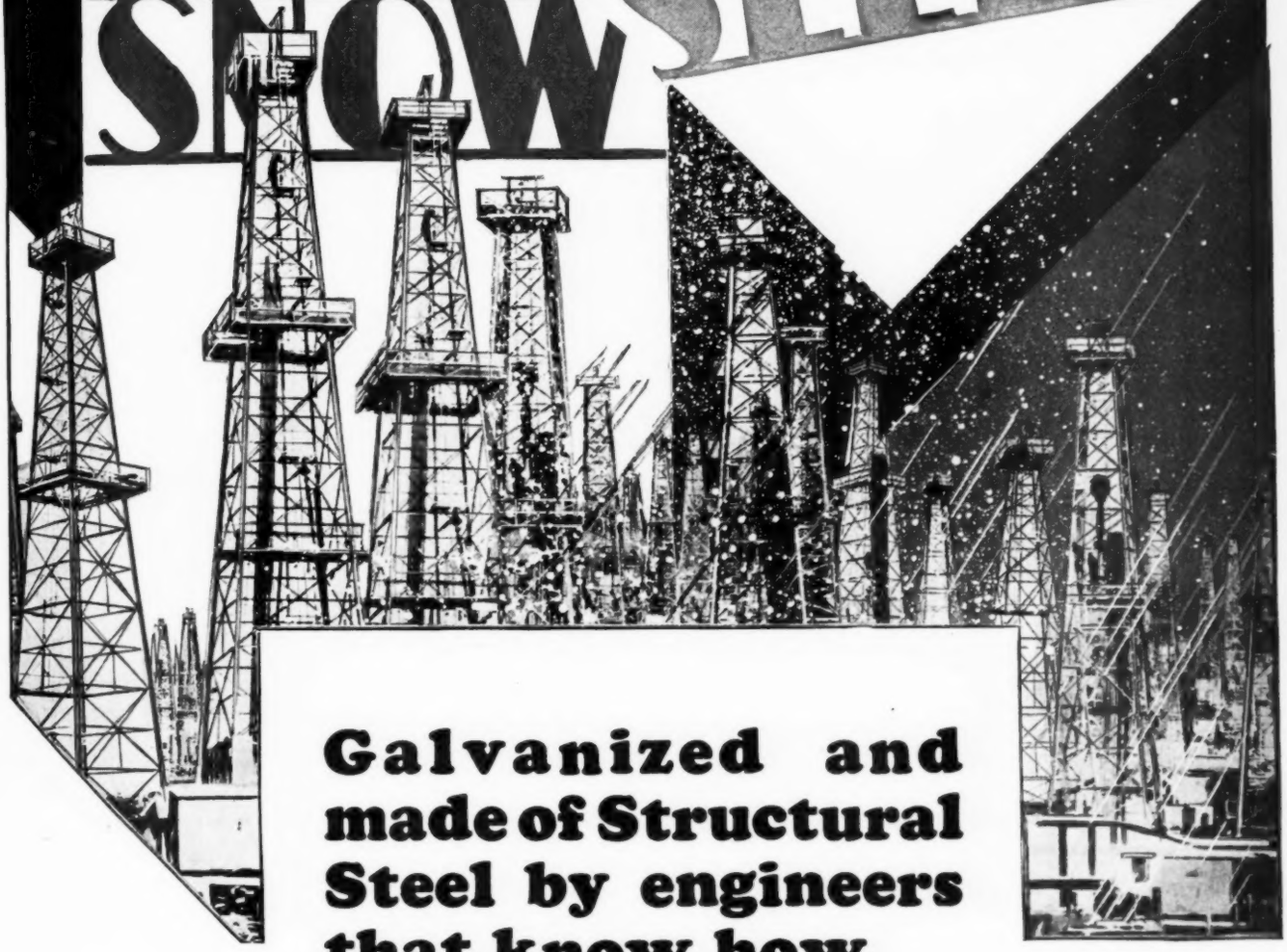

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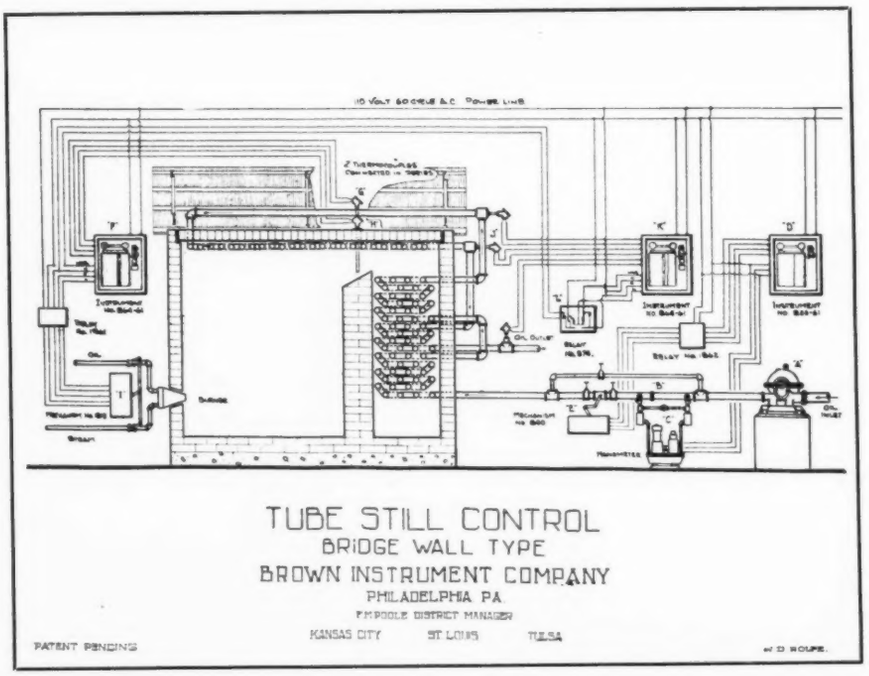
top tray. To illustrate how much difference this makes, note the Chart "A," photostats Nos. 1, 2, 3 and 4, which have self-explanatory notations on them. The record shown is from an older type of control—the "off and on" type—which is now becoming obsolete, but the comparison of thermocouple location should hold, regardless of the type of control.

Unfortunately, little thought, comparatively, has been given to improving furnace thermocouples. It is becoming more and more evident that furnace thermocouples, as now used, do not tell the whole story of furnace temperature. When one considers that in modern furnaces 60-75 per cent of the heat transferred is into the oil by radiation and only 25-40 per cent by convection, and that furnace thermocouples are affected primarily by conviction, it is evident that some improvement is in order.

In the resistance thermometer we have an electrical instrument, of indicating or recording type, which is particularly adapted to low temperature work—whether 200° F. below zero or 200° F. above zero. A brief exposition of this instrument, which involves a wheatstone bridge, a galvanometer, a battery, and sensitive element known as a resistance bulb, is especially opportune in view of the extraordinary care and additional equipment being used to improve and free wax from lube oil, and also in view of the new methods being advocated for natural and refinery gas analysis.



In passing to the second part of this discussion, there is no question but that automatic control is the phase that is becoming more and more useful and from which more can be expected in the future. In speaking of automatic control, a more broad interpretation is required. Real automatic control—from which great things can be expected—is not the isolating of one particular factor, such as tower outlet temperature, and the building of a control for that temperature, but rather the adapting of a synchronized control for all the factors present. For example, in the refractionating end, the tower outlet temperature should be blended with the liquid level and possibly also with vacuum controls. In the tube still end, the furnace and oil temperatures controls should be linked with flow control.

It is in this larger sense that the instrument manufacturer who is in a position to build these various types of controls can be of real service to the refiner.

To illustrate such blending, note Diagram "B" of typical tube still control:

Oil is pumped into the still tubes by the pump, A. The pressure differential across the orifice, B, operates the manometer, C, which causes the rate of flow to be recorded by the automatic control recording flow meter, D. This instrument causes the valve, E, to operate when the rate of flow rises or falls above or below a predetermined amount, thus maintaining correct oil feed to still.

At the same time, the automatic control recording pyrometer, F, is recording individually two thermocouples, G and H, located one at each end of the furnace, also recording and controlling from the average still furnace temperature above the bridge wall by means of the thermocouples, G and H, which are connected in series as point No. 3. When the furnace temperature shifts from the point it is desired to maintain, the pyrometer operates the valve, I, regulating the oil burner feed, and the proper temperature is automatically and promptly restored.

Theoretically, if the oil is fed to the tubes at the rate determined correct under average conditions and the furnace is maintained at a constant temperature found satisfactory for that rate of oil feed, the oil temperature at the outlet should be continuously correct. In practice a number of variables upset such a constant hot oil temperature.

To compensate for these variables and act as a safety protection, the temperature of the oil leaving the roof tubes is taken by means of the thermocouple, J, connected to the automatic control recording pyrometer, K. Variation in the oil temperature from the predetermined maximum point causes the pyrometer to operate the relay, L, nullifying the furnace control, and at the same time reducing the fuel and holding it reduced until the oil temperature falls below the predetermined point—after which the furnace control, F, again resumes adjustment.

It should be noticed that one of the attendant hazards, usually present in the use of automatic control, is recognized and taken care of in this scheme. The natural reaction of the fireman, who is given automatic furnace fuel control, is to rely on it, which means less time spent around the furnace burners proper. To eliminate this hazard, by giving the fireman something definite to do regarding which he is checked, and at the same time so designed that the "heat input" is not affected if he neglects to do his part, the furnace pyrometer "P" is built as a three record instrument. Two of these records record only the temperatures of thermocouples G and H. The fireman is given the responsibility of keeping his burners together so that these two records are together; if he fails to do so, his error is shown by diverging records.

As mentioned, the real growth in the future will come in automatic control. This year has seen material development in temperature, liquid level and flow control. Vacuum control of the barometric type for low absolute pressures, independent of atmospheric variation, has been added. These have proven of real value in new vacuum distillation units. The next year will see real achievement in blending these controls, synchronizing them to give an even more satisfactory result.

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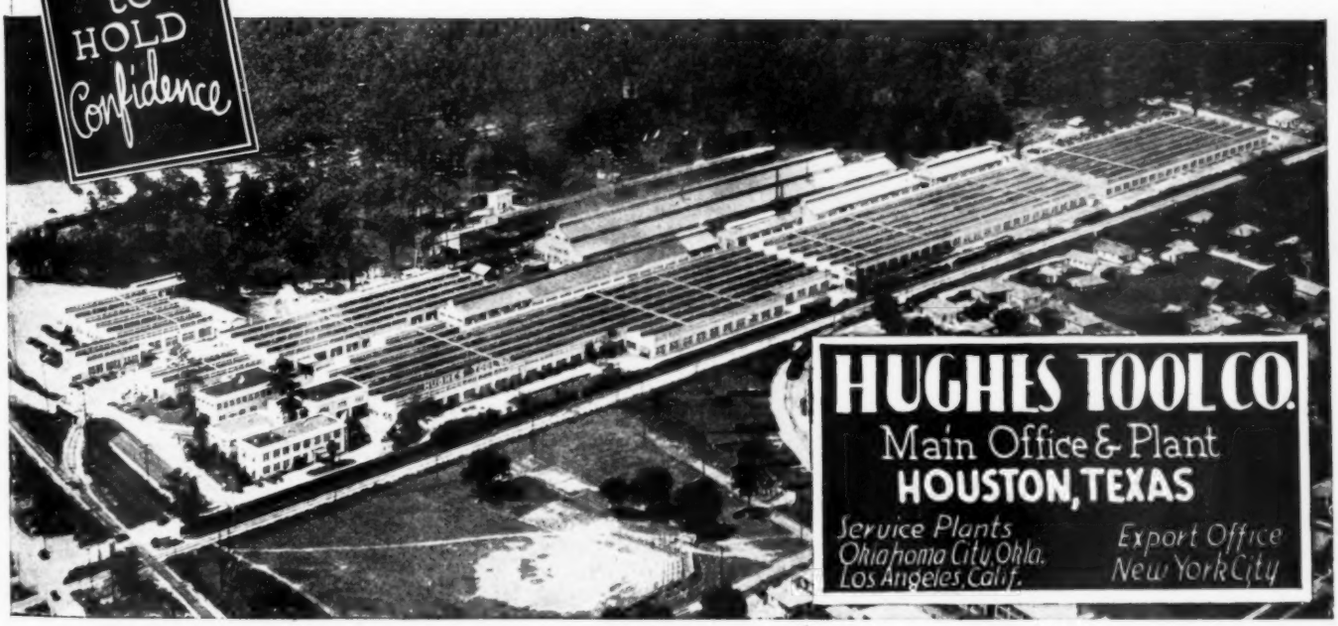

The Hughes Tool Company Plant at Houston, occupying more than 8 acres of floor space—employing more than 3,300 men—manufacturing Hughes products for use in the Rotary Oil fields of the world.

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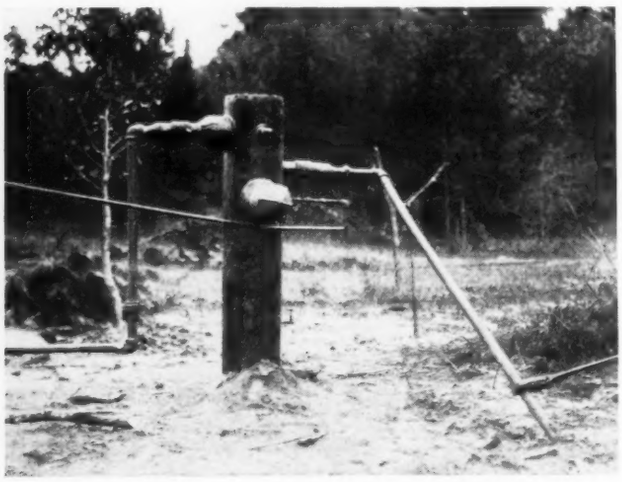
Gas Well *and* Main Line Drips

By ROBERT WETZEL,
Assistant Superintendent Lines, Magnolia Gas Co.

IN the operation of gas lines the continuous and unrestricted flow of gas from the well to the point of delivery is the ideal condition. Oil gasoline, water, sand, or mud entering gathering lines from the well with the gas stream can quickly upset field operations. Due to drop in temperature or reduction of velocity on entering lines of larger diameter, water or gasoline condensing from the flowing gas, causes obstruction in main lines by collecting in the low points or sags, thus reducing the area of the gas



A Wetzel drip installed.

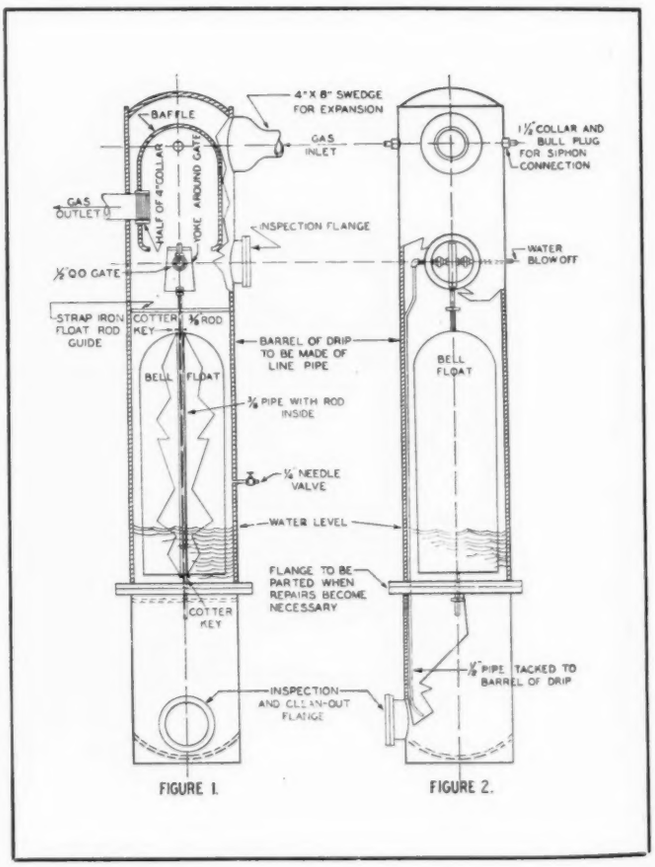
passage and causing pressure loss and check of flow by restriction. "Flour" sand and dust particles passing through regulators and fittings damage operating equipment by abrasion of valve seats and clogging of tubes and orifices.

Drips must be designed to cause the least possible resistance to flow and subsequent reduction of pressure. For this reason the stepladder drip which takes advantage of reduction of velocity without reduction of pressure is the most popular. This drip consists of an enlarged section of pipe to which legs or small diameter outlets are connected on the bottom permitting the liquid to fall into a reservoir from which it can be drawn through a blow-off line. This drip is only partially efficient and then only when located on the upper slope and down stream from sags, where condensed liquids follow the bottom of the line. This drip can be improved by proper location of baffles in the enlarged upper barrel. Improperly located baffles tend to prevent satisfactory operation by causing turbulence and eddying currents which whip the condensed liquids back into the gas stream in the form of mist. When the drip is improperly located, there is a tendency for the gas stream to partially channel through the storage barrel and pick up part of the removed liquid and carry it back into the line.

A number of drips are in common use which take advantage of velocity change through enlarged pipe sections and direction change by the use of baffles and tees. Most of these retain the fault of keeping the removed liquid in storage in contact with the flowing gas until the drip is "blown off" by hand with waste of gas.

There are several unique features embodied in the Wetzel drip that so far are not found in similar devices. These features are:

1. Designed for pressures up to 2,000 lbs. per sq. in.
2. All of the working parts of the drip are inclosed in the barrel, and hence are protected from corrosion of the elements, tampering, and damage from objects blown by the wind or from stray animals.
3. There are no toggles, cams, or joints in the operating mechanism of the drip which can become stuck or easily broken.
4. The discharge is operated by a bell float of comparatively large dimensions, which increases the potential buoyancy of same, allowing only sufficient weight to insure positive operation of the blow-off valve.
5. There is no possibility of gas being wasted because the opening of the blow-off line in the drip is under a liquid seal.
6. The float works on a guide rod which insures smooth operation regardless of the exact vertical setting of the drip barrel.
7. The drip permits safe and efficient withdrawal of gas from wells through siphon lines because of no appreciable drop in pressure of the gas passing through the drip.
8. Dependent only on the gas pressure, the drip will discharge into a storage tank at any desired height above the drip or into a collecting line against a pressure slightly below the gas pressure in the drip.



Many Difficulties Encountered in

Extinguishing *a* Burning Gas Well

RECENTLY the Sinclair Oil & Gas Co.'s No. 3 Stamper in the Oklahoma City Field (a 100,000,000 foot gas well) started one of the most spectacular well fires in Mid-Continent history. The huge gasser caught fire at 3:00 A. M. on a Tuesday morning and its blazing torch quickly reduced the steel derrick to a twisted mass. After the blaze had been conquered, the well still bent on its destructive ways, started cutting down a new steel derrick that had been skidded in place. It was closed in a few moments later.

M. M. Kinley

Most of the drama of the spectacular fire was packed in the brief time three men worked their way close to the inferno to place a gelatin shot in position to extinguish it. The Kinley Torpedo Co. was given charge at 3 P. M. Tuesday afternoon. To M. M. Kinley, whose experience in subduing Mid-Continent major well fires is wide, this was the hottest. Water thrown on the ground near the well boiled away.

After clearing away debris, giving the ground a chance to cool and making preparations, Mr. Kinley, his brother, F. T. Kinley, and R. R. Brandenthaler of the U. S. Bureau of Mines, made their way into the intense heat as water was showered on them, placed the shot and fled. They dressed much in the fashion of the field worker, wearing only a couple of shirts additional. While advancing they were both hot and cold, the intense heat of the flames kept their faces burning hot, while the cool water played upon them from the rear caused a different temperature on that side.

Making preparations for the shot required several hours of work and entailed several disappointments. The twisted steel derrick had to be cut away, section at a time, then the derrick legs had to be cut and the remaining part of it pulled away with tractors. After that, water lines were in readiness.

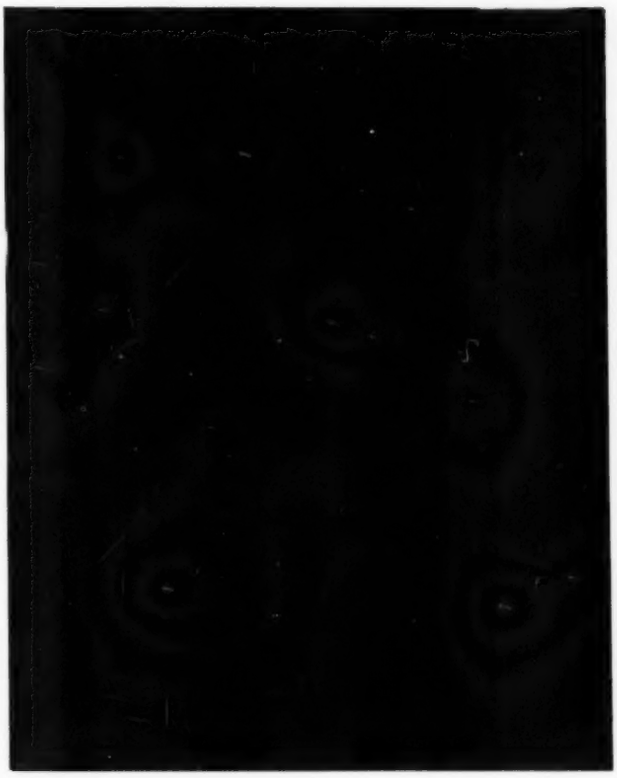
Daylight Thursday morning was set as the zero hour to discharge the shot. Accordingly, at 4 o'clock crews were on hand making final preparations. A shifting wind caused a delay. Before that time the wind had constantly blown from the south. It shifted to north, making it necessary to change the water lines so the streams would not be thrown against the wind. After this had been done, the wind then changed to the south. The lines were then brought through the engine house. This proved a beneficial move because the wind was blowing through the house keeping it cool. The gelatin shot was prepared in the engine house, and the water lines extended near the fire through what was left of the belt house.

The hog trough method of placing the shot was used. It was a V-shaped trough, long enough to be extended diagonally across the width of the derrick floor. To keep it from igniting, it was covered with tin. One end was anchored to a barrel placed over a derrick leg and then the trough was moved close to the casing head.

With the caution and skill of years of experience, the Kinley brothers worked their way close to the fire, shoving the charge of explosive ahead of them in the trough. As they did, Mr. Brandenthaler, stationed to one side of them, played a stream of water on the men and shot also a small stream on himself. When the charge had been placed opposite the well head and a short distance away, all three fled for fear that the charge would be prematurely exploded by a falling object or moved by well pressure.

A few seconds later, the 31-quart shot made a sharp report, created a vacuum between the column of gas and the flame. The flame, severed momentarily from its fuel supply, shot skyward and a roaring column of gasoline-saturated gas followed, but did not ignite. The blazing torch was out.

The skill of the well-fire specialists was further revealed when the connections were examined. All connections, save the gate valve, were intact. It had been turned around by the detonation, but sand had cut most of it out before the shot.



The Sinclair gas well blazing at Oklahoma City. Photo by courtesy The Daily Oklahoman. (See front cover.)

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RULES
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...Anyone is eligible except employees of Merco Nordstrom Valve Co. or affiliated companies

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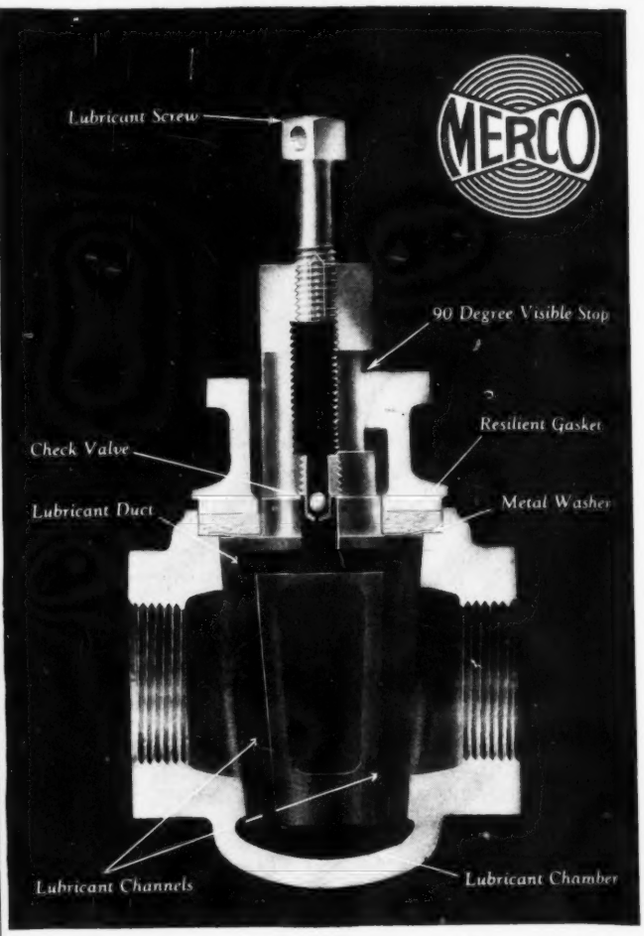

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Methods of

Tubing High-Pressure Wells[1]

By H. C. OTIS,*
Shreveport, La.

DURING the past year or two considerable time and money have been spent in developing equipment for tubing large-volume high-pressure oil and gas wells without loss of production. That the efforts have met with success is proved by the fact that any properly cased well, regardless of its production or regardless of its rock pressure or working pressure, can now be safely tubed with no appreciable loss of production, provided experienced crews handle the new equipment.

It is conceded that a far better gas-oil ratio can be secured by flowing a well through tubing of a proper diameter—the diameter of the tubing depending, of course, upon the volume of fluid and gas and the depth of the well—than by the more usual method of installing a choke at the mouth of the well. Where possible it is becoming the practice to bring wells in through tubing, though in the majority of instances this is not feasible. In many instances it has developed, after a well has been brought in through tubing, that the tubing installed is either too large or too small for the most efficient operation or that the well had not been drilled deep enough.

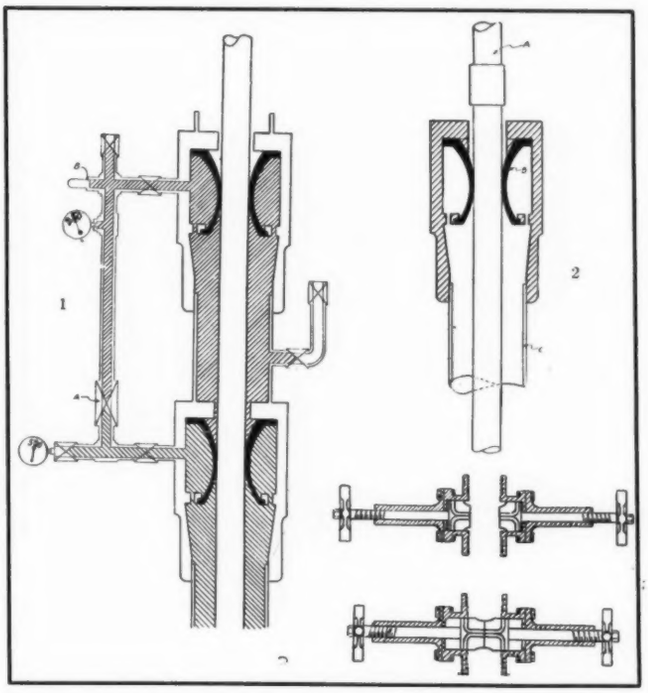

Fig. 1.—Two low-pressure tubing control heads mounted together with regulated by-pass.

Well pressure assumed to be 500 lbs. Lower area (lines running left to right) is under 500 lb. pressure.

A = small spring-type regulator, maintaining 250 lb. on outlet side, causing upper area (lines running right to left) to be under 250 lb. pressure.

Relief valve B set at 260 lb., to relieve excess pressure set up either through failure of regulator A or through leakage between tubing and lower control-head rubber.

There is then exerted against outside of lower rubber a pressure of 500 lb. and against inside of this rubber a pressure of 250 lb., resulting in an effective pressure of 250 lb. against this rubber. A similar effective pressure of 250 lb. is exerted against upper rubber, 250 lb. being against its outside and atmospheric pressure against inside.

Fig. 2—Low-pressure tubing control head.

A, tubing; B, control-head rubber; C, casing or well connections. Gas or fluid pressure from well forces rubber B against tubing A and makes a seal between tubing and rubber.

Fig. 3—High-pressure tubing control head.

In upper drawing, rams that form gas or fluid-tight seal around tubing are open; in lower drawing, they are closed.

The equipment described in this paper, in the hands of experienced men, permits the tubing of these wells after they have been brought in, with the size of tubing then determined by actual observation to be best suited for each particular well, and with no danger of the well getting out of control, of catching fire, of drilling itself deeper, or of any loss of production. The deeper the flowing production with the consequent future higher lifting costs, the more essential it is that the size of tubing used be such as to give the best possible gas-oil ratio. The ability to bring in these deep wells through the casing and then, immediately after their completion, regardless of volume or pressure, to tube them with the size of tubing that permits the most efficient use of the gas present will doubtless save many dollars.

[1] Presented before the Fall Meeting of the A. I. M. E., Tulsa, Okla.
*Arkansas Natural Gas Corp.

Uses for the New Equipment

The equipment permits a further step in the operation of wells where the conservation of gas is of major importance. Perhaps 3-in. tubing will give the most efficient operation at the outset in some particular well. After either the oil or the gas flow has declined to a certain point, 2½-in. tubing and later 2-in. tubing will be necessary to maintain that same gas-oil ratio. With the equipment described, it is possible to plug the tubing in the well, to snub it out of the hole and then to snub in pipe of the proper size; all with no waste of production and with no danger to the workmen or to the well. The reverse operation is at times desirable. By agreement production may be curtailed to the point where 2-in. tubing gives the desired ratio. Later, restrictions may be lifted so that 2½-in., 3-in. or 4 in. tubing may be used. This desired change can be readily and safely effected.

In other instances, where flush production is known to pass off quickly and is followed by the use of air-lift, and where the field is under severe competition, the ability to tube the well for the use of airlift before the natural flow has declined has a distinct value in that it permits the use of a gradually increasing amount of air or gas to augment the supply of gas in the sand as it diminishes—never permitting the flow of oil to stop. It is the usual practice now to permit the natural flow to continue until it stops, then to tube the well and again start the flow into motion with either air or gas. Theoretically and practically this practice of permitting the flow of oil to stop for even a few hours is bad, and is not necessary.

The production of high-pressure natural gas also carries with it situations under which the ability to tube or siphon a well, regardless of its pressure or volume, without permitting the escape of any appreciable amount of gas during the operation, is of extreme value. Water troubles are not confined to low-pressure, small volume wells. The Richland Parish, Louisiana, gas field is a striking example of such a situation. Here wells of from 50,000,000 to 60,000,000 ft.

(Turn to Page 55, Please)

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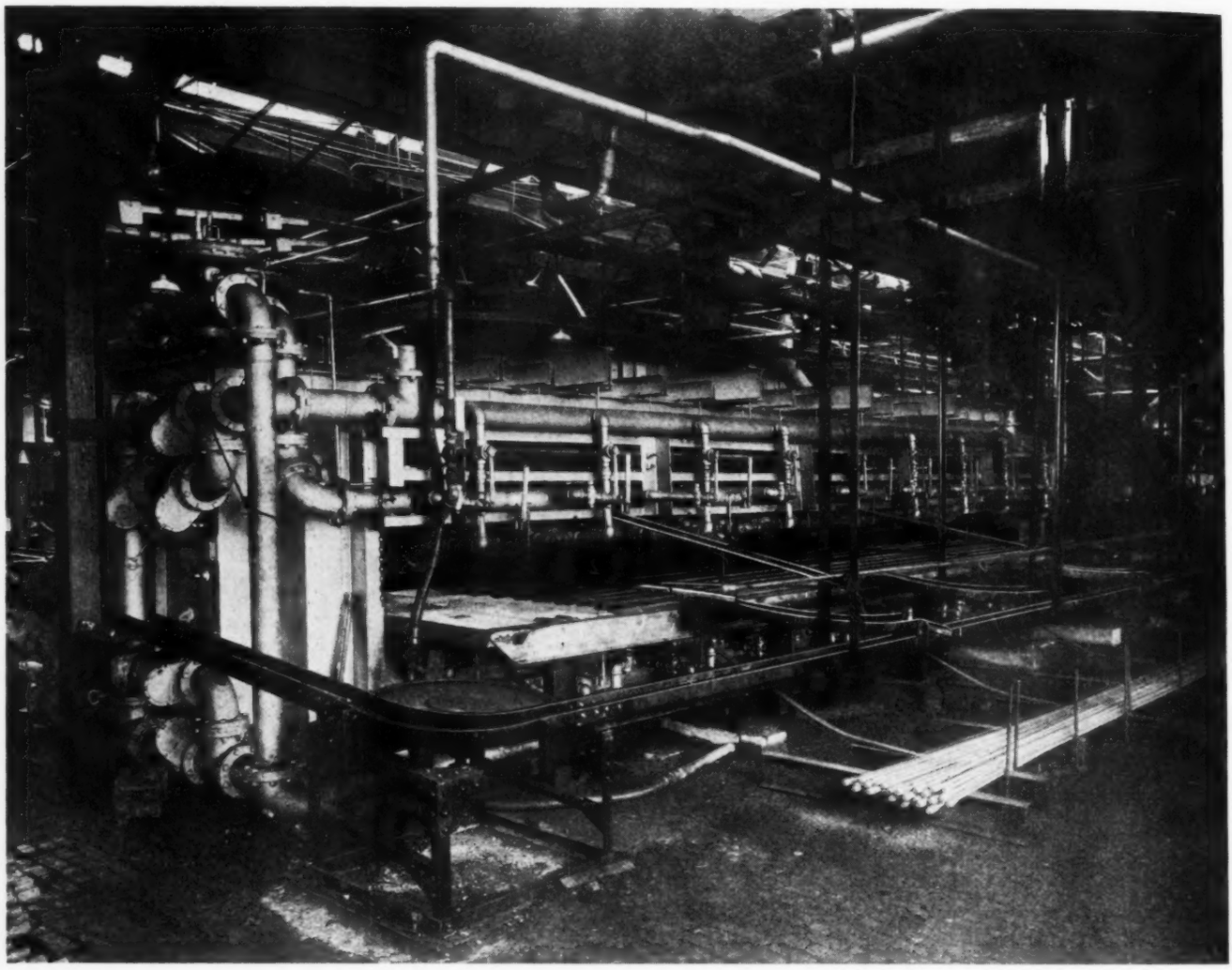

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open-flow capacity with rock pressures up to 1,100 lb. are the rule. After a comparatively short pull, water puts in its appearance, not in large quantities, but rapidly enough, in the course of a month or so, to build up a head in the well that seriously affects its working pressure and delivery capacity. It is not safe, because of danger to the well connections and the almost certainty of drilling the well deeper, to open these wells into the air to remove this accumulated head of water. Siphons then are necessary to successful operation. For various reasons the wells are not brought in through tubing, so tubing must be run after completion of the wells. Any method of siphon installation that would permit the escape of gas and sand would be almost certain to end in disaster, therefore the operators have welcomed methods of installation that permit the safe, even if not advisable, lighting of a cigarette only a few feet from the well connections at any time during the installation.

There are also other uses for the equipment. Occasionally, in rotary drilling, a well blows in with no liner in the hole. This, of course, often happens in cable-tool drilling. As much as 100 ft. of liner or screen of the desired diameter can be run to bottom, with the well feeding through the side connections or not, as may be desired, during the operation. Occasionally a well blows in with the drill pipe still in the hole. It is not, as a rule, a difficult matter to plug the bottom joint by use of a small packer and then to snub the pipe out through control heads—all without loss of production.

Description of New Equipment

Control Heads

There are two general types of tubing control heads (Figs. 1-3), each of which has its advantages and disadvantages. In one of these types a gastight or fluid-tight seal around the pipe being run is maintained by a rubber ring forced tightly against the pipe by the gas or fluid pressure in the well. This rubber expands to permit the passage of couplings. As long as this rubber remains intact, no material leakage can take place. The advantages of this rubber-packed type lie in the fact that the well itself furnishes and regulates the pressure which forces the packing against the pipe and in the fact that there is no delay in passing couplings. One disadvantage lies in the fact that since the rubbers must be flexible enough to expand and allow passing of the pipe couplings, it follows that there is a limit to the thickness and consequent strength which can be built into them. Experience seems to indicate that they are not safe, particularly on long strings of upset pipe, for working pressures over about 300 lb. Two makes of control heads of this type allow for the use of two rubbers, on the theory that double protection is thus afforded. The installation of a regulated by-pass from one head to the other, having the effect of stepping down the effective pressure against each rubber, materially increases the working pressures against which this type of head can be used. A further disadvantage in the use of these heads lies in the fact that if, during the snubbing operation, the pipe should get out of control and start out, there is nothing built into the head itself that will prevent its being blown clear out of the hole. One specialty company, I believe, is attempting to work out a model that will remedy this disadvantage.

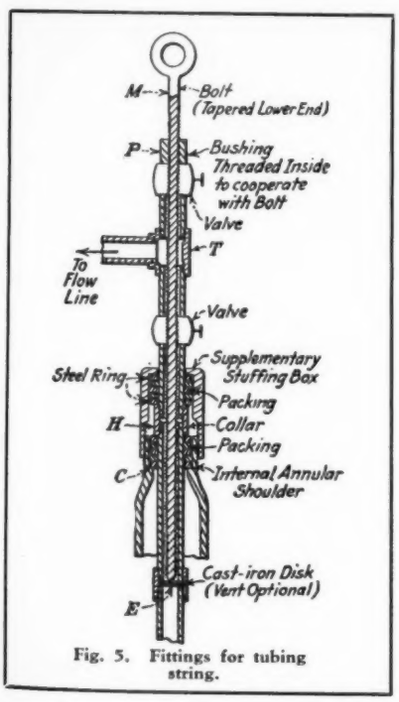

Fig. 5. Fittings for tubing string.

The other type of control head uses steel rams, bored to completely encircle pipe of the desired diameter and faced with sections of hydraulic or composition packing. These rams are manually forced against the pipe being run by various screw mechanisms, and a shut-off secured, to any desired degree. It is necessary to use two of this type of head on each well, to permit the passage of couplings, for if one alone were used, when it was opened to permit the passage of couplings the well would be free to blow into the atmosphere and would soon blow out the packing, and if sand were present would soon ruin the face of the rams. This type of control head can be built to withstand any desired pressure and has the further advantage that if the pipe should start out of the hole it could not move for more than the length of one joint, because, when the rams are in the closed position, a coupling cannot pass through them. Since, however, two sets of rams must be manually opened and closed for the passage of each coupling, this type of control head is slower in operation than the first type mentioned. Either type, when used with the snubbing and packing assembly to be described later can be repacked in a few minutes at any time during the running of the pipe, and either type of head can be salvaged after the pipe has been landed on bottom.

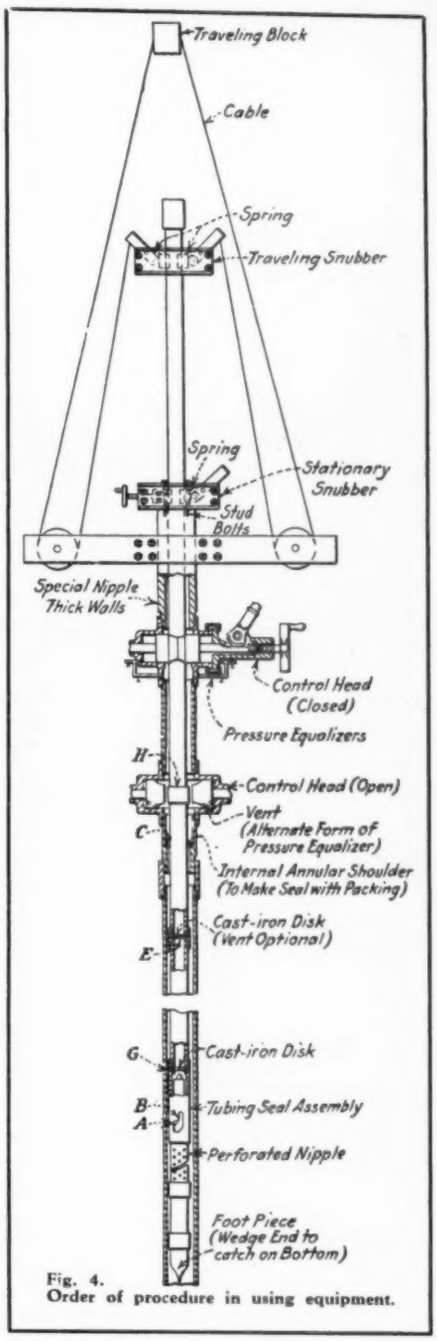

Fig. 4. Order of procedure in using equipment.

Snubbing Equipment

Installing tubing against working pressures in excess of 1,000 lb. necessitates the use of rapid and safe snubbing

equipment. Approximately one foot of pipe of any diameter must be snubbed for each pound of working pressure on the well. From a rather crude start, a thoroughly reliable mechanism has been worked out. It has two principal members—the traveling snubbers and the stationary snubbers. The function of the former is the actual forcing of the pipe in against the well pressure, while the function of latter is to grip the pipe and prevent it from being blown from the hole while the traveling snubbers are being raised for a new bite. The stationary snubber is preferably bolted directly to the casing. A nipple with thick walls is screwed into the top control head, this being the top member of the casing string during the tubing operation. The walls are made thick enough for holes to be bored and tapped vertically for stud bolts which pass through the side members and hold the snubbers firmly in place.

One of the dogs of the stationary snubber is pivoted, the other is adjustable and not pivoted. The adjustable dog is held by two pins which extend from the side members through horizontal slots in the dog. By means of a hand wheel and screw, it can be moved toward the tubing to grip it tightly in co-operation with the pivoted dog or to back away far enough from the tubing to permit passage of couplings.

The pivoted dog is pivoted upon a pin immovably attached to the side members of the stationary snubbers. It is not adjustable toward or from the tubing, but can swing about the pivot pin to permit the tubing to pass downward between it and the adjustable dog. The pivot pin is higher than or on a plane above the serrated portion of the dog, so that upward movement of this portion will also move it inward toward the adjustable dog, firmly gripping the tubing and holding it against upward motion through the snubber.

The pivoted dog consists of two members, one with an arcuate serrated face to bear against the tubing and pivoted upon or pinned to the end of the other member, which is a lever or fulcrum and is itself pivoted or pinned to the side members of the stationary snubber. This flexible connection of the two members of the dog permits maximum gripping effect of the bearing face by assuring vertical alignment against the tubing.

The traveling snubbers are made up of two pivoted dogs identical with that used in the stationary snubbers. A cable passes from the lever end of one of these dogs down to a sheave pivoted in one end of a pair of casing clamps fastened immediately below the stationary snubbers, up through a tubing block or the center sheave of a traveling block, back down through a sheave in the other end of the casing clamp and up to the lever end of the other dog. Upward movement of the tubing or traveling block results in a downward movement of the traveling snubbers, which carry the tubing along with them. The stationary snubbers permit free downward movement of the pipe. When the traveling snubbers have been pulled down to the stationary snubbers they are raised for a new grip by lowering the traveling block. During this movement the stationary snubbers prevent the pipe already snubbed into the hole from being blown out again. After sufficient pipe has been snubbed in to cause it to fall of its own weight the snubbing equipment is easily removed so as not to interfere with the remainder of the tubing operation.

Device for Closing Bottom of Tubing

Various means of closing the bottom of the tubing to prevent flow of oil or gas through the tubing until after landing on bottom have been experimented with. The old method of simply inserting a thin cast-iron disk between two joints of pipe, this disk to be broken by dropping a weight from above, is not recommended because of the undesirability of leaving a weight in the hole, and the possibility of damaging the string of pipe or of damaging the screen, if one is used. Closing devices which require unscrewing to open after landing on bottom are objectionable, particularly when used with the smaller sizes of pipe.

A method of breaking a cast-iron disk from the underside, without dropping a weight from above or without screwing or unscrewing, has been worked out. The assembly consists of a forging of the same outside diameter as the couplings in the string and about 9 in. long. The upper end of this forging is threaded on the inside with a straight thread down to a shoulder, the inside diameter of this shoulder being the same as that of the tubing being run. A thin cast-iron disk and gasket are laid on top of this shoulder and a short combination nipple jammed against it to form a tight seal. A sliding nipple of the same inside and outside diameter as the remainder of the string operates in the lower part of this forging and is fastened in the forging by two dogs, which operate both vertically and horizontally in slots cut in the forging. While running in the pipe these dogs are held to the left of the lower section of the slot. If the condition within the well is static, with no flow, the dogs will be hanging in the lower end of the slot, while if sufficient fluid or gas flow is present to raise the weight of the screen and anchor below, the dogs will be held up against the upper left-hand corner. The wedge on the bottom of the string is shaped roughly like a fishtail bit, any fluid flowing past it tending at all times to keep the dogs thrown to the left. A thin pointed steel bridge is built over the top of the sliding nipple. While the dogs are at the left of the slot this bridge cannot come up against the cast-iron disk. After the pipe is landed on bottom and the upper portion of the string turned a short distance to the right so that the upper portion of the slots is above the pins, the string drops approximately ½ in., causing its entire weight to be thrown upon the center of the cast-iron disk and easily shattering it. The thin bridge does not materially obstruct the tubing, and if any great amount of fluid or sand is following quickly cuts out anyway.

Operation of Tubing Equipment

The procedure is shown in Fig. 4, as follows: The tubing is lowered until it rests upon the bottom of the well. This does not telescope the tubing seal assembly and break the disk G because the pins A are not in position to enter the straight portion B of the slots. Measurements are taken, the tubing is raised, cut and threaded at a point which will be some short distance X inches below the internal annular shoulder C. A coupling and a tubing nipple about X inches long is then screwed upon the tubing where it was cut and threaded. A cast-iron disk E is made up here in the coupling, being held in place between the two pipe ends. This disk E may have a small bore or vent through it, the purpose being to permit some leakage at this point for determining by observation when the seal at the lower end of the tubing has been broken. Since the disk is loosely retained in the coupling between the pipe ends, the leakage around the edges may be sufficient when high pressures exist in the well; therefore the bore or vent may be desirable in some cases and not in others. It would usually be omitted when oil is present in high-pressure wells to prevent a spray of oil upon the workmen during subsequent operations.

More tubing is coupled to the string and it is again let down against the bottom of the well. The tubing is turned to the right at the top, and since the footpiece catching on the bottom of the well prevents the part below the seal from turning also, the slots B are brought over the pins A, allowing the pipe to drop, telescoping the tubing seal assembly and breaking the disk. The oil or gas in the well can then flow through the tubing up against the disk E. Its loose fit

(Turn to Page 61, Please)

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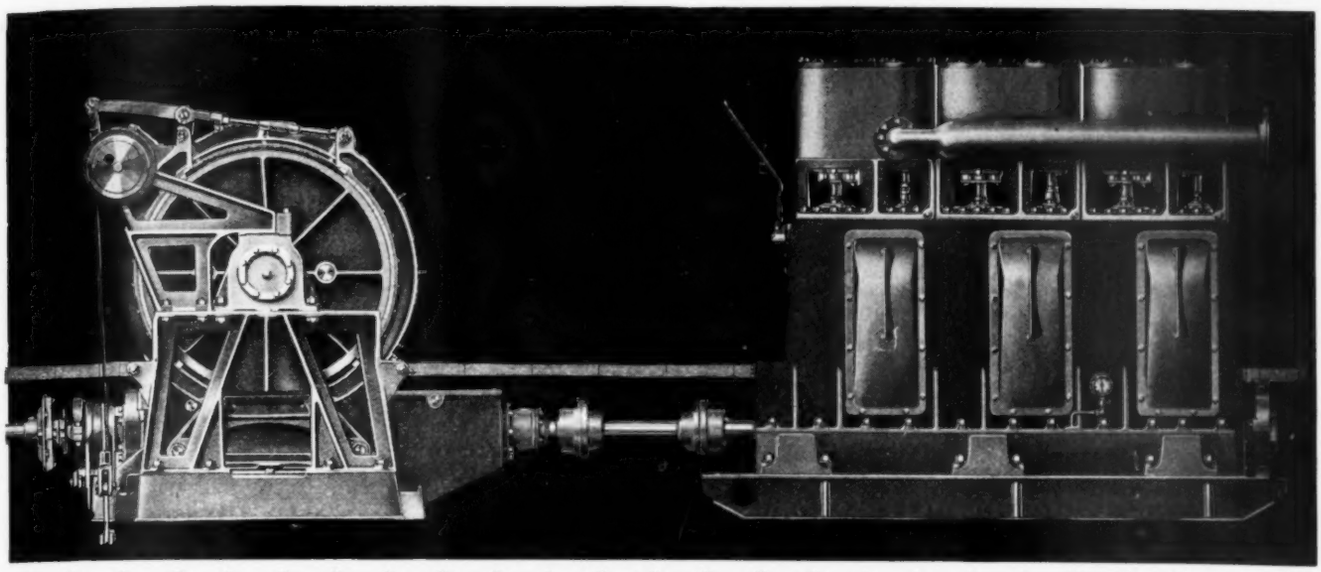

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17,114 feet of hole in 10 wells, depths 1,540 to 1,819 feet, 1,711 feet average, *drilled with HYDRIL No. 2*
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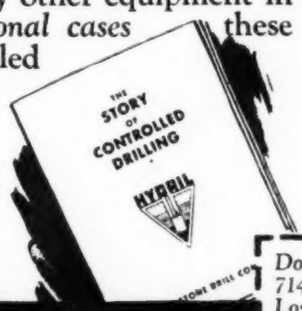

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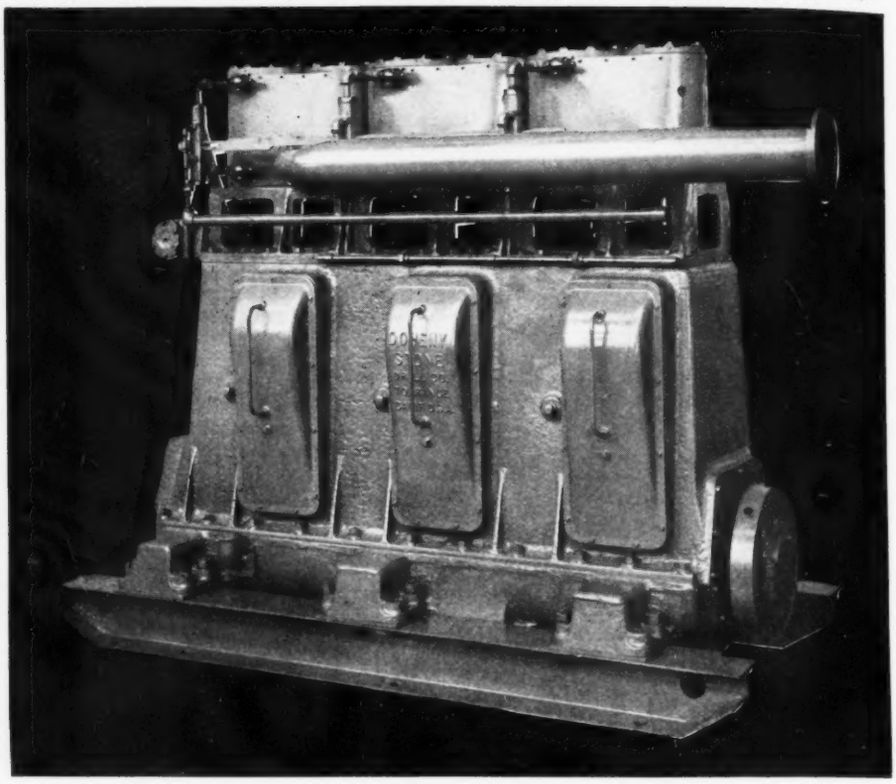

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Diameter exhaust pipe	3"
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Diameter crank shaft	4⅝"
Diameter crank shaft pins	4⅝"
Diameter cross head pins	2½"
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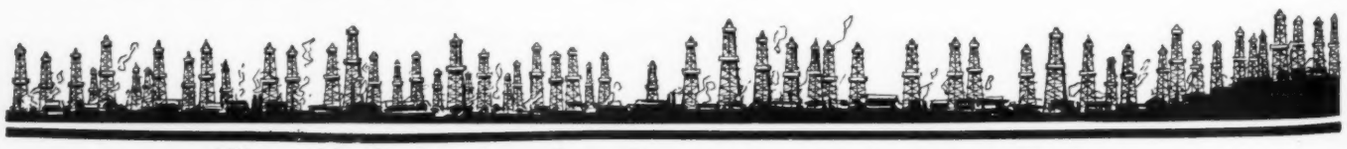

and the small aperture allow enough leakage to ascertain that the lower disk *G* has been broken. The tubing is again raised, two steel packing rings with packing between them are put around the tubing immediately below the coupling *H* and the tubing is again lowered. The steel rings are made so that they cannot pass through the inner annular shoulder *C* and the coupling *H* cannot pass through them. The weight of the tubing, therefore, compresses the packing between the outside of the tubing and the inside of the casing. The inner annular shoulder *C* must, of course, be small enough to prevent the passage of the steel packing rings. It may sometimes be in a nipple with the same exterior diameter as the rest of the string of casing, as shown in Fig. 4 or it may be, and usually is, contained in the narrow part of a swedged member as shown in Fig. 5.

After this packing operation is completed, the two control heads and everything else made up in the casing string above the packing may be taken off. Then the part of the tubing string above the packing may also be removed. Gas from the well is leaking out of course, through or around the disk *G* from the time the lower disk is broken, but it is in such small quantity that it does not interfere with subsequent operations.

The fittings shown in Fig. 5 may then be assembled to the tubing string at coupling *H*. These fittings consist of the two valves shown and the T between them, which are permanent connections, and the bolt *M* and bushing *P*, which are used to break the disk *E* and then are removed. The well is connected to the flow line through the branch of T. Both valves are opened and the bolt *M* is screwed down through the bushing *P* until its tapered point bears against the disk *E* and breaks it. The well can flow out through the T and into the flow line. The bolt *M* is then backed up by unscrewing until the upper tubing valve can be closed. Then the bushing *P* and the bolt *M* may be unscrewed and removed and the end of the tubing permanently closed with a plug or cap, completing the operation.

If desired additional steel packing rings and packing between them may be put around the tubing above the coupling *H* to supplement the packing below. This can be tightened, as shown, by means of a member that screws down over the threads upon the upper end of the top member of the casing string, which will be threaded down far enough to give sufficient take-up in the stuffing box.

Time will not permit detailed description of the various other methods of using the equipment. Briefly, when it is desired to set liner in a producing well, one tubing control head is made up at the top of the well connection, four or five joints of 6 or 8-in. pipe are made up just above this, and two control heads and the snubbing equipment put in place. The liner is made up inside of the 6 or 8-in. running up into the derrick, and is connected to the tubing by a left-hand nipple, "J" tool, or any other of several possible methods. With the tubing control head that is immediately above the well fittings wide open, and with snubbing operations conducted from the top of the 6 or 8-in. pipe near the fourble board of the derrick, enough tubing is snubbed into the well to bring the top of the liner beneath the lower control head. This control head is then closed around the tubing, the few joints of pipe in the derrick are broken down, and the remainder of the snubbing operations are conducted from the usual platform a few feet above the floor. Recently 75 ft. of 4½-in. perforated liner was run in this way into a 45,000,000-ft. gas well having 750 lb. working pressure, with no loss of production. In this instance this was probably the only method by which the liner could have been put into the well. It could not have been dropped into the well while blowing because of the large quantities of shale and rock that would have been blown out and because of the certainty of gutting the well. Lubricating was not considered safe.

Pulling tubing or drill stem out of a well under pressure is accomplished by lowering a small packer through the tubing or drill pipe, the packer being run on a steel measuring line through a stuffing box. The measuring line is released when the packer reaches bottom and is pulled out of the hole. The packer is set by opening a valve on the tubing or drill stem just below the stuffing box, the differential set up by the flow past the packer expanding the rubber and effecting a seal. The pipe is then snubbed out of the hole, using the same equipment that is used to snub it in.

The equipment and process described, save for the control heads, were developed by the Southern States Co. of Shreveport, La. Patents have been applied for. During the past year and a half this company has successfully tubed over 150 oil and gas wells—wells under working pressures ranging from a few hundred to 1,200 lb. per sq. in.—with virtually no loss of production in any instance. Against 1,000 lb. or more an average of perhaps 12 hr. is required after setting up for running a 2,000-ft. string and about 25 hr. for a 5,000-ft. string.

Discussion

MR. WILKINS described methods of tubing high pressure wells similar to those presented in the paper except that snubbing equipment was not used. Wells making fifteen to twenty million feet of high pressure gas, and 1,000 barrels of oil were tubed with very little loss of oil or gas. A Guiberson oil saver was used and speed in running tubing was increased by prior making up of the tubing in stands. The initial rock pressure in this area was from 1800-1900 lbs. per sq. in.

In regard to gas-oil ratios, minimum gas-oil ratios were obtained by tubing a well immediately it was completed. A 5300-ft. well was tubed to 5,000 feet, and a reduction in gas-oil ratio from 25,000-30,000 cu. ft. to 15,000 cu. ft. per barrel was obtained. The gas-oil ratio was still further reduced to 9,000 cu. ft. by running an additional 200 ft. of tubing in the well.

Large Laboratory Batch Still Constructed for Experimentation Purposes

A large laboratory batch still, designed by chemists of the San Francisco laboratories of the United States Bureau of Mines, Department of Commerce, is being constructed at the Bureau's San Francisco field office. This apparatus when finished will be the finest and latest type of its kind in operation. It will be entirely automatically controlled and the tower will be practically adiabatic, which should result in the best possible fractionation.

A combination manometer and vacuum regulator has been designed, constructed and tested, which will make it possible to control the vacuum in the fractionation system to within a variation of 2 microns. This, so far as is known, is the most sensitive of any regulator that has heretofore been constructed. When the construction work has been completed, exhaustive tests will be made on crude oil from various California fields.

SIR HENRI DETERDING, managing director of the Royal Dutch-Shell oil interests, will come to the United States early in December to address the annual meeting of the American Petroleum Institute. W. R. Boyd, Jr., executive vice-president, making the announcement, said:

"Sir Henri Deterding has accepted our invitation and promised to come to this country early in December to speak before the annual meeting of the Institute on the subject, 'Common Sense in the Oil Industry'."

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Many Plants Now Giving Attention to

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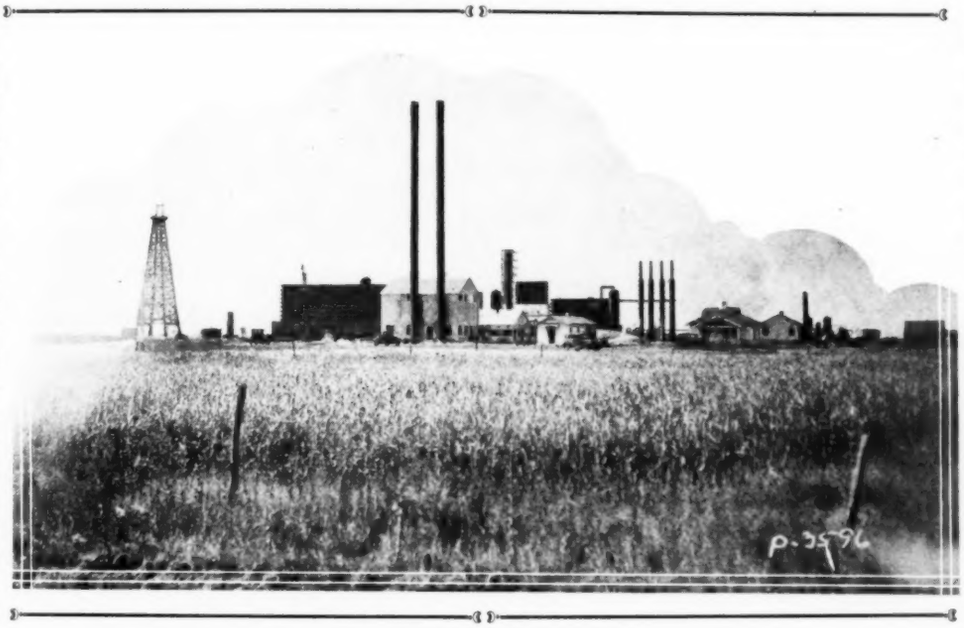
MANY refiners are taking advantage of the present market conditions by manufacturing motor fuels having characteristics superior to those required by U. S. Motor Specifications. It is now well established that volatility and anti-knock performance are the most desirable characteristics of gasoline for the modern high compression engine. As a result of this, the refiner is giving more attention to quality than to yields, since a small sacrifice in the quantity produced is more than offset by the additional profit accruing from the premium price.

Rectified gasolines, propane free, having end points between 350° F. and 400° F. and high anti-knock ratings are now available to the motorist. The elimination of the heavier ends usually improves the knock rating, and minimizes troubles due to gums and loss of color in sunlight, although most premium gasolines are colored with analine dye.

The anti-knock properties of a motor fuel depend upon the crude from which it is distilled, its distillation range, and the cracking process by which it is produced. The lighter or lower boiling hydrocarbons of a given series will show less knocking tendency than the heavier members, and aromatics and olefines less than paraffins. The manufacture of anti-knock gasoline by the various cracking processes often involves the problem of gum formation and odor. The seriousness of this condition depends upon the type of process used, the crude oil source, and geographic location of the refinery and market.

Volatility

The work of Doctor G. G. Brown of the University of Michigan and other authorities shows that the 10% point on the A. S. T. M. distillation curve indicates the minimum temperature at which a car can be started without using the choke. The significance of this point was considered by the Federal Specification Board in the new U. S. Motor Gasoline Specifications. In manufacturing motor fuel of proper volatility the refiner should consider vapor pressure to avoid vapor lock troubles. The loss on distillation is not an accurate method of controlling volatility. The naphtha from the gasoline recovery plant should be stabilized before blending into motor fuel. The use of fractional analysis to control the lighter fractions in motor fuel is a very satisfactory method. By this method the exact percentage of each of the various light hydrocarbons is determined. The manufacture of more volatile gasoline of low end point will result in a larger demand for certain grades of natural gasoline. This product is also beneficial in reducing the gum content without reducing the knock rating.

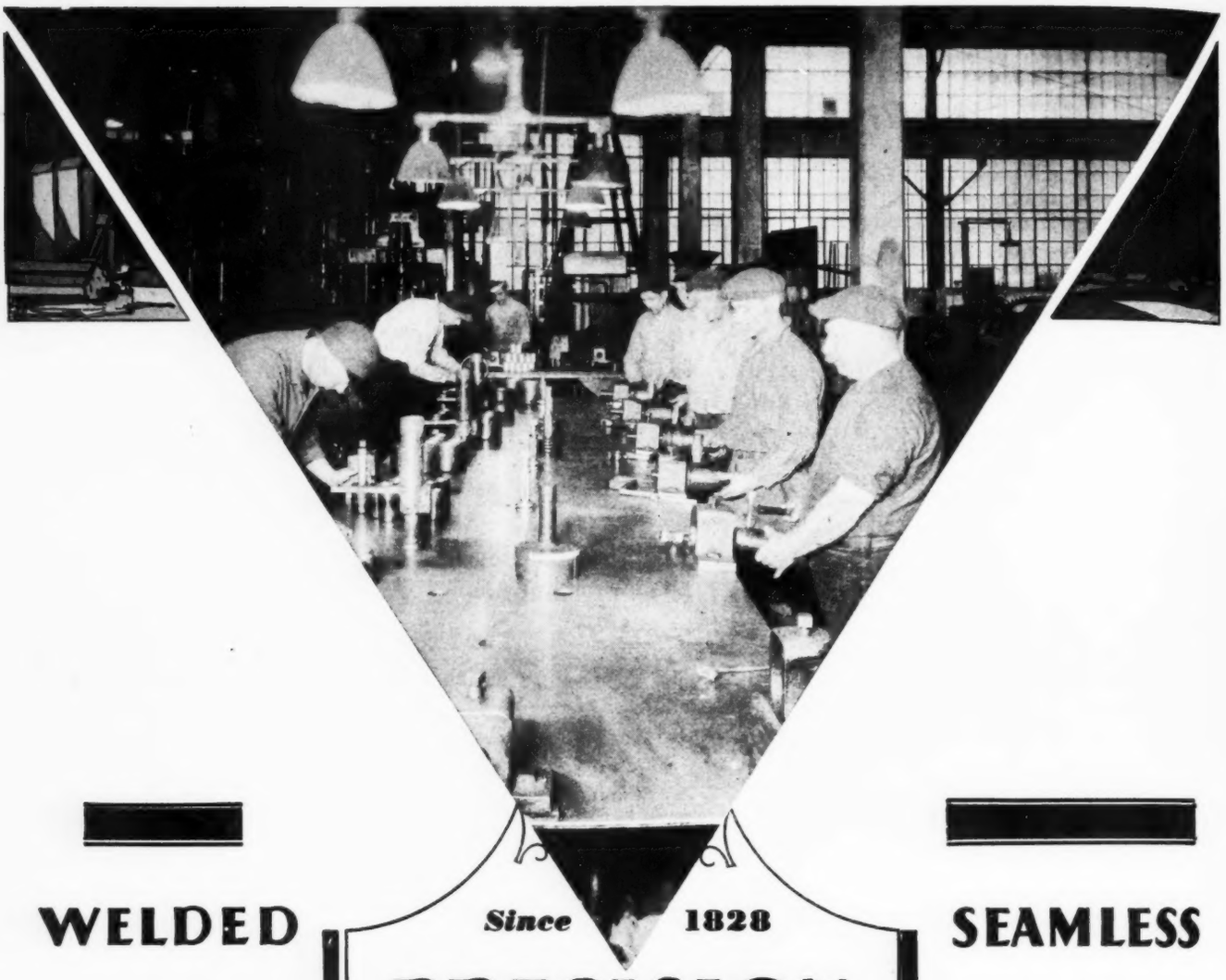


Gums

Most cracked gasoline contains gums or compounds that will form gums in storage due to oxidation. This reaction is accelerated by heat, sunlight, lead compounds, and various other factors. It is the problem of the refiner to eliminate gum trouble without destroying anti-knock properties of the gasoline. To start with the standard copper dish method is not satisfactory to determine gum content. The work of Voorhees and Eisinger shows a definite distinction between gum content and potential gums which might be formed in storage. The most successful method of treating or refining a distillate to produce the best gasoline is almost an individual problem for each type of crude and cracking process used. There are usually several distinct methods of treating a given product, and the choice of the most economical and efficient method to produce the desired product should be worked out in the laboratory.

The standard procedure in this country for treating cracked distillate is with the use of sulphuric acid, followed by neutralization with caustic soda, and sweetening with plumbite solution. It is then rerun with fire and steam, and this distillate again sweetened. Rerunning under reduced pressure or steam distillation without fire produces a more stable product in some cases. The acid plumbite treatment is the most effective and flexible, being applicable to nearly any distillate. The products from certain crudes, however, will not produce stable gasoline when plumbite is used to sweeten. Heavy gum formation and rapid loss of color in storage is experienced. In such cases sulphuric acid and a caustic soda wash is used, which produces a stable non-corrosive product, slightly sour to the doctor test. The acid plumbite method is the most satisfactory one for treating gasoline from high sulphur crudes.

Vapor phase refining has many advantages in producing stable gasoline of low gum content. It has its best application in refining distillates from sweet crudes. When the sulphur content of



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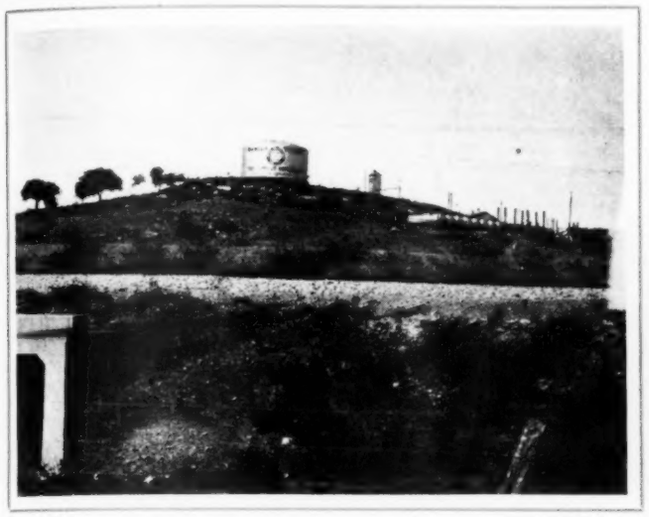
the product is high, acid treatment is imperative. The profitable use of vapor phase refining for certain crudes is becoming more widely recognized by the refiner, with the result that many new units are being installed.

Contact filtration to stabilize cracked gasoline is used by some refiners. The use of specially refined or treated clay in the very fine state should be given more consideration, as it offers a great many possibilities as a refining reagent. The results and efficiency obtained is largely dependent on the kind of clay and the method of treating it. Fine clay refining has extensive use in manufacturing lubricating oils,



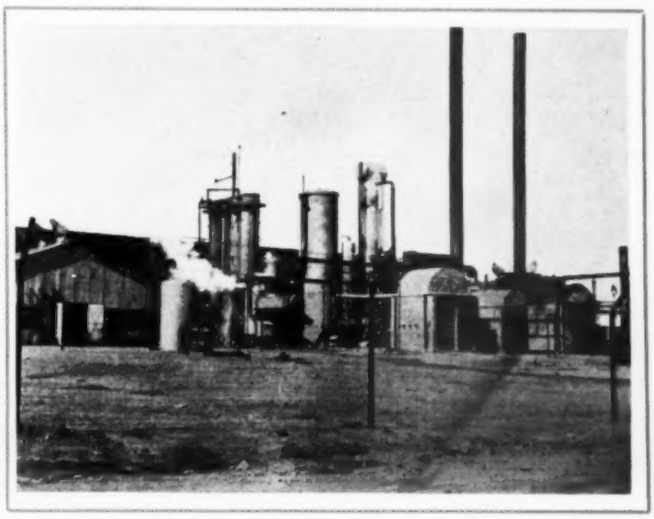
but its use in light oil refining has not yet been fully developed.

Anti-knock Testing

Much work has been done in the study of anti-knock fuels during the past few years, but intensive research work on knock testing has only recently been developed to a point where technologists feel safe in adopting a standard testing apparatus. Scientists of the Bureau of Standards and several technical societies have been working on the problem during the past year. The various types of knock testing engines used in the industry are based on one of two principles. The Midgley bouncing pin is most widely used in this country on an engine of fixed compression ratio, while in Europe, and to an extent here, the variable compression engine is used. The maximum useful compression ratio for a given fuel is determined. At the present time, numerous types of engines are in use for testing anti-knock fuels, and until a machine and method is standardized, difficulties and lack of uniformity in results in determining the knock rating of a fuel will exist.

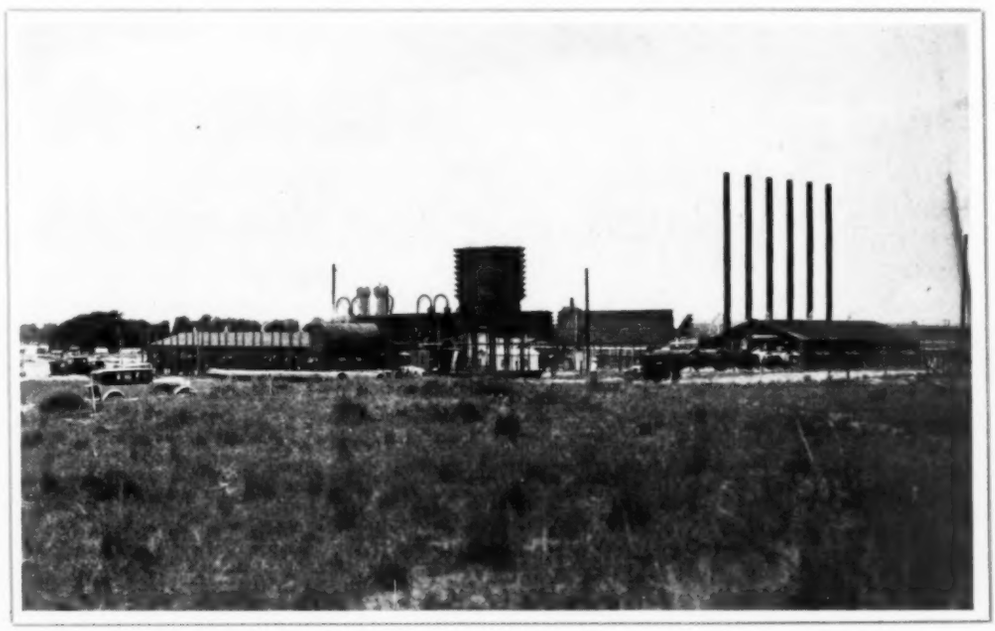
Ethyl Gasoline

The extensive advertising of the Ethyl Gasoline Corporation during recent years has educated the motorist to the advantages and uniform quality of ethylized gasoline, so that a growing demand for this type of motor fuel has been pro-



duced. Many refiners from coast to coast are now licensed to ethylize their motor fuel. An untreated gasoline of high anti-knock rating to start, will require less lead tetraethyl or ethyl fluid than one of poorer quality; consequently, the profit will be greater on such a product. From one to four c.c. of the lead compound is used to produce ethyl gasoline. The corporation maintains rigid sulphur and gum specifications, and specifies the distillation limitations.

In view of the present economic conditions in the industry, the refiner is finding advantages in manufacturing and increased profit by producing premium gasoline of proper volatility and low end point, whether he markets an anti-knock fuel containing ethyl fluid or not. By leaving out the heavy ends, the knock rating and gum tests are improved, and usually better stability in storage results.



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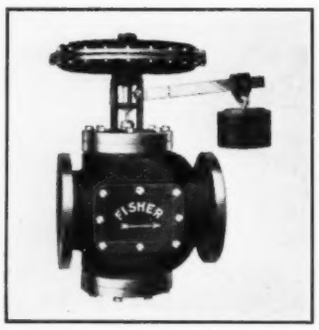

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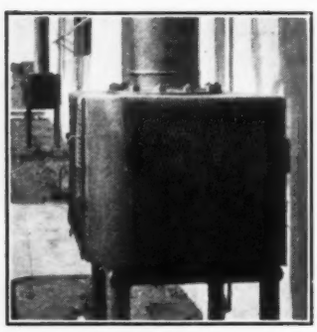

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The Quantitative Effect of Gas-Oil Ratios *on the Decline of Average Rock Pressure*[1]

By STEWART COLEMAN[2], H. D. WILDE, Jr.,[3] *and* THOMAS W. MOORE[4]

IT is a well recognized fact that in the early days of the Petroleum Industry oil was produced with practically no scientific or fundamental knowledge of the laws and principles governing its extraction from the ground. Only a few, if any, of those exploiting the oil resources made any effort to collect accurate scientific information. There was little need for it, for as is frequently the case where the supply of a natural resource appears inexhaustible and is greater than the demand, large profits were possible from merely skimming the surface with little regard to the efficiency or thoroughness with which the oil was obtained. With this policy in force, great quantities of gas were wasted and when the reservoirs ceased producing by natural means they still contained a large fraction of the oil originally in them.

The present tendency in the industry is toward conserving existing oil reserves. In order that greater percentages of the oil present in the ground may be recovered, efforts are being made to improve production methods and to rework old depleted fields. If the production methods are to be improved intelligently it is essential that the fundamental laws be known and understood and consequently at the present time a large amount of money and effort is spent in gathering data that will serve to define and interpret these laws.

A great deal of attention is being focussed on the study of the motion of oil through an oil-bearing sand, the forces that cause it to move and the factors that affect its motion. It is recognized that one of the important factors is pressure, but its quantitative effect is not known. In a given field the rate of production declines with time and so does the rock pressure. Furthermore, a comparison of different fields shows, as a rule, that those with the greater initial rock pressure have the greater initial production. This leads naturally to the conclusion that the production rate is roughly proportional to the rock pressure and it is plausible to assume that if steps be taken to make the rock pressure decline more slowly than it would under natural operating conditions the production rate will decline less rapidly. If this is so, the ultimate recovery under those conditions should be greater. Quantitative evidence concerning the effect of pressure maintenance on the rate of production is lacking but it is hoped that future investigations will show what it is.

There are two methods by which the decline of rock pressure can be retarded. One is to control production of the oil in such a manner that the amount of gas removed from the reservoir with a given amount of oil is lower; for the lower the gas-oil ratio, the more slowly the pressure will decline. A second method is to return to the oil-bearing reservoir all or a portion of the gas that is brought to the surface with the oil. This is equivalent to a reduction of the gas-oil ratio equal to the difference between the total gross gas produced and that returned.

It is of considerable value to know quantitatively what change in the decline of rock pressure would result from a change in the gas-oil ratio. With such a relation it would be possible to predict the change in rock pressures with various production methods. It would show, for instance, what rock pressures could be expected if a program of repressuring in the early life of the field were made effective and how great a fraction of the oil could be produced before the rock pressure would fall to a given value. This information would serve as a basis for estimating future increased production to be expected from an early repressuring project.

Inasmuch as a natural flowing well will continue to flow as long as the pressure at the bottom of the well is sufficiently great, maintenance of rock pressure at a high level should lengthen the flowing life of a field. Since lifting costs in pumping wells will average around twenty-five cents (25c) per barrel, the economic value of maintaining a high rock pressure is manifest. Pressure maintenance is of value from this point of view even if there is no increase in the total oil recovered. To establish the relation between gas wastage and rock pressure would be essential in making an economic balance between the cost of gas injection and the saving of lifting costs and would determine whether the cost of a proposed project of early repressuring would be justified on the basis of saving in lifting costs alone.

This paper presents one derivation of a mathematical relation between the amount of gas wasted from the formation and the average rock pressure after a given fraction of the oil has been removed.

Derivation

The only assumptions necessary in the derivation of this equation are: (1) That there is no water drive. (2) That the solubility of the gas in the oil follows Henry's Law, i. e., the volume of gas (measured at standard conditions) dissolved in a unit volume of gas-free oil is directly proportional to the gas pressure. This last assumption is justified by the work of Beecher and Parkhurst, Dow and Colkin, Mills and Heithecker, and others, who have found a linear relation between the pressure and the amount of gas dissolved.

The terms and symbols used in this paper are defined as follows:

Gas-free oil is dead oil resulting when the pressure is reduced to zero pounds gauge or, in other words, is oil saturated with gas at one atmosphere.

Original conditions are the conditions of pressure, temperature, sand saturation, etc., existing in the reservoir just prior to the time the first well is drilled.

The volume of the reservoir is understood to mean the total volume of all the pore space in the sand.

x is the fraction of the gas-free oil originally in the reservoir that has been removed up to a given time. The gas-free oil originally in the sand is therefore equal to 1.

P is the original rock pressure expressed in atmospheres.

p is the mean rock pressure in the reservoir after a given

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[1] Presented at meeting of Petroleum Division, American Institute of Mining and Metallurgical Engineers, Tulsa, Oklahoma, October, 1929. Subject to Author's revision.

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[3] Director of Production Research, Development Department, Humble Oil & Refining Company.

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fraction of the oil, x has been removed. This is also expressed in atmospheres.

k is the constant in the expression for Henry's Law; amount of gas dissolved = kp.

a is the co-efficient of volume expansion due to the solution of one unit of gas in one unit of gas-free oil. Thus the total volume occupied by the mixture of oil and gas when one volume of gas-free oil is saturated with gas under the pressure p is $(1 + akp)$.

y is the fraction of the total gas originally in the reservoir wasted in producing x volumes of oil. When gas is returned to the reservoir, only the difference between the total gas produced and that returned is considered as wasted.

m is the ratio of volume of reservoir filled with free gas at pressure P to volume filled with oil.

g is the mean amount of gas wasted with each unit of gas-free oil produced divided by the total amount of gas in the reservoir per unit of oil under the original conditions. Therefore, $y = gx$. If r is the mean gas-oil ratio (cubic feet of gas per cubic foot of oil) during production,

$$g = \frac{r}{mP(1 + akP) + kP}$$

In the derivation to follow, all volumes are expressed in cubic feet. Volumes of the gas-free oil, the total liquid and the space in the reservoir, being independent of the pressure, are expressed in cubic feet and are not corrected for pressure. But all volumes of gas are expressed as the number of cubic feet the gas would occupy at one atmosphere of pressure and the reservoir temperature.

As all volumes, whether of the liquid, gas, or space in the reservoir at any time will be expressed in terms of a fraction of the gas-free oil originally present, it is immaterial, for the purposes of the derivation, how much oil is originally present in the reservoir.

In order to simplify the mathematics of the derivation, it is assumed that the reservoir originally contains one cubic foot of gas-free oil. The relation thus derived may be applied to any given reservoir, for the rock pressure after one-half the oil is removed under a given set of conditions is the same whether the oil originally contained in the reservoir was one cubic foot, a million, or any multiple of one cubic foot.

The volume of the gas-free oil at the start is equal to 1; of the liquid is $(1 + akP)$; and of the free gas is $m(1 + akP)$. The total volume of the reservoir is the sum of the last two or $(1 + akP) + m(1 + akP)$.

After x volumes of gas-free oil have been removed from the reservoir:

$(1 - x)$ = volume of gas-free oil remaining in the reservoir.

$(1 - x)(1 + akp)$ = volume of liquid remaining in the reservoir.

The volume of the free-gas space in the reservoir will be equal to the total volume of the reservoir minus the volume of the liquid or

$$[(1 + akP) + m(1 + akP)] - (1 - x)\ (1 + akp),$$

which is equal to

$$x(1 + akp) + ak(P + Pm - p) + m.$$

$(1 - x)kp$ = volume of gas dissolved in the saturated oil remaining in the reservoir. (Measured at atmospheric pressure and the reservoir temperature.)

The total volume of gas (measured at atmospheric pressure and reservoir temperature) remaining in the reservoir will be equal to the sum of gas dissolved in the oil plus the gas occupying the free gas space in the reservoir, so,

$(1 - x)kp + p[(1 + akp)x + ak(P + Pm + p)] + m =$ total volume of gas remaining in the reservoir.

The volume of gas remaining in the reservoir may be expressed in another manner, for since the volume of gas dissolved in one cubic foot of gas-free oil under original conditions is kP and the volume of free gas associated with it is $m(1 + akP)$, and as y(or gx) is the fraction of this gas which has been wasted.

$(1 - y)\ [(1 + akP)\ Pm + kP]$ = volume of gas remaining in the reservoir.

Equating these two expressions we have,

$$(1 - x)kp + p[(1 + kp)x + ak(P + Pm - p) + m] = (1 - y)[(1 + akP)m + kP] = (1 - gx)[(1 + akP)Pm + kP]$$

For a given field a, k, m and P are fixed and when g is set at any desired value the only variables are p, the rock pressure, and x, the fraction of the oil produced. The natural procedure in using this equation would be to assign a value to x, and solve for p, but since the equation is a quadratic and p and only linear in x, it is simpler to express x in terms of p. Thus expressed the equation becomes

$$x = \frac{m(P + akP^2 - akpP - p) + k(P - p - apP + ap^2)}{m(gP + gakP^2) + (1 - k)p + akp^2 + gkP} \quad (1)$$

For a field where all the gas in the formation is held in solution, *i. e.*, there is no free gas, m becomes equal to zero. This simplifies the above equation to—

$$x = \frac{k(P - p - apP + ap^2)}{(1 - k)p + akp^2 + gkP} \quad (2)$$

Numerical Illustrations

The manner in which these equations can be used is best illustrated by means of numerical examples. A hypothetical case will be used, but the conditions assumed will not differ materially from those existing in an actual field.

Consider an oil field under the following conditions:

1. The original rock pressure, P, is 100 atmospheres (1470 pounds per square inch).

2. At 100 atmospheres and the reservoir temperature, 240 cubic feet of gas are dissolved per barrel of gas-free oil, giving a solubility of 42.6 cubic feet of gas per cubic foot of oil. In this case, k=0.426 cubic feet of gas (at standard conditions) dissolved per cubic foot of oil per atmosphere of pressure.

3. When saturated with gas at 100 atmospheres, the volume of the mixture is 10 per cent greater than the volume of the gas-free oil. Therefore, a=0.00234.

4. The porosity of the sand is uniform throughout and has a normal value so the sand is "open." The formation is not lenticular, but forms a single reservoir. The wells are evenly spaced so that the same average rock pressure exists in the various portions of the reservoir.

Case 1. 10% *Free-Gas in the Reservoir at the Start and All Gas Produced Returned to the Reservoir.*

For these conditions m=1/9, as volume of free-gas voids is 10% and volume of oil filled voids is 90%, and since no gas wasted, g=0.

Substituting values of a, k, P, m, and g in equation (1), we have—

$$x = \frac{54.5 - 0.645p + 0.001p^2}{0.577p + 0.001p^2 + 0}$$

Curve No. 1 is plotted from this equation. In this chart the values of p found from the equation have been multiplied by 14.7 in order to express the pressures in pounds per square inch.

Case 2. *No Free-Gas at Start and All the Gas Returned to the Reservoir.*

In this case $m = 0$; $g = 0$.

Substituting values of a, k, P, and g in equation (2) we have

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CONTINENTAL

$$x = \frac{42.6 - 0.523p + 0.001p^2}{0.577p + 0.001p^2 + 0}$$

Curve No. 2 is plotted from this equation.

Case 3. *No Free-Gas at Start and Gas Wasted Equal to Original Solubility.*

In this case m=0; g=1. The mean gas-oil ratio during production is 240 cubic feet per barrel of oil.

Substituting values of *a, k, P* and *g* in equation (2) we have—

$$x = \frac{42.6 - 0.523p + 0.001p^2}{0.557p + 0.001p^2 + 42.6}$$

Curve No. 3 is plotted from this equation.

Case 4. *No Free-Gas at Start and Gas Wasted Equal to Five Times Original Solubility.*

In this case g=5; m=0. This is equivalent to an average gas-oil ratio of 1,200 cubic feet per barrel of oil.

Substituting values of *a, k, P* and *g* in equation (2), we have—

$$x = \frac{42.6 - 0.523p + 0.001p^2}{0.577p + 0.001p^2 + 211.5}$$

Curve No. 4 is plotted from this equation.

Case 5. *Gas Wastage Changed During Production.*

The four examples cited above apply to conditions where a given average gas-oil ratio prevails from the start of production up to the point in question. There are many cases to be considered where one ratio prevails for a part of the time and thereafter the ratio is changed decidedly, as for example where repressuring is started after the field has produced oil in the normal manner. In this case a curve should be drawn representing conditions up to the time of the change. The value of p at the time of the change becomes P for a new equation and the new m can be calculated from the original value of m and the value of x. The new values of x calculated from this second equation will be expressed as fractions of the oil in the formation at the time the change is made and not of the oil originally in the reservoir. It is an easy matter, however, to convert these values of x into a set expressed in terms of the original oil content of the reservoir. The following calculation illustrates a case described above:

Assume that the conditions represented by curve No. 4 held until the pressure falls to 590 pounds (40 atmospheres). By this time 0.095 or 9.5% of the gas-free oil has been produced. At this point repressuring is started with the result that net gas-oil ratio drops from 1,200 to 140 cubic feet per barrel.

Computation will show that when the repressuring is started, there is a ratio of 140 cubic feet of gas to each barrel of oil left, and, therefore, for the new equation, g=1. Since m is defined as the ratio of the reservoir space occupied by free gas to that occupied by liquid—

$$m = \frac{(1 + akP) - (1 - x)(1 + akp)}{(1 - x)(1 + akp)}$$

Substituting 40 for p, and 0.095 for x, m comes out equal to 0.164.

Using $k = 0.423$, $a = 0.00234$, $P = 40$, $m = 0.164$, and $g = 1$, a pressure decline curve can be calculated. The results of such a calculation, expressing x in terms of the oil originally present, are plotted as curve No. 5.

Practical Applications

The relation between the gas wastage in a given field and the decline of the rock pressure can serve as the basis for a number of important calculations. Several of the applications will be discussed briefly, as it is impossible to go into much detail without making the paper unduly long.

Curves can be drawn using this equation that show the relation between the gas-oil ratio and the rate at which rock pressure in a reservoir declines. For example, curve No. 2 represents a case where all of the gas is returned to the reservoir and the net gas-oil ratio is consequently zero. This curve shows that returning all of the gas does not maintain the pressure at its original value, as is sometimes supposed, but that the pressure will gradually decline. If it were possible to remove every bit of the oil, the pressure would finally fall to 564 pounds, which is 38.4% of the original rock pressure. The rock pressure after any given fraction of the oil has been produced can be predicted from this curve.

Curve No. 3 is for a case where the original reservoir conditions are the same as for No. 2, but the net gas-oil ratio, or the gas wasted, is equal to the gas originally dissolved in the oil. For the assumed field, it is a ratio of 240 cubic feet per barrel. Here the pressure declines much more rapidly than for curve No. 2, and the pressure will fall to atmospheric at the time all the oil is removed.

Curve No. 4 is similar to the other two except that the net gas-oil ratio is fivefold the original solubility, or 1,200 cubic feet per barrel. In this case the pressure declines very rapidly, reaching atmospheric when only 20% of oil has been produced. Similar curves could be drawn to illustrate other ratios, but these should suffice, as they clearly indicate the trend.

This equation can be used to illustrate the marked effect that small increases in the gas-oil ratio have on the maximum amount of oil recoverable and to point out the importance of keeping the gas-oil ratios at the lowest possible value. The following table is calculated for a reservoir under the conditions assumed above:

Average Gas-Oil Ratio	g	Value of x When p Becomes Zero
240	1.0	1.00
360	1.5	0.67
480	2.0	0.50
720	3.0	0.33
960	4.0	0.25
1200	5.0	0.20
1800	7.5	0.13

It is evident that the values in the third column are reciprocals of g.

It must not be inferred from this table that if the gas-oil ratios given there prevail, that it is possible to produce the corresponding amounts of oil given in the third column. If it be granted that gas energy is the force that moves the oil to the well, there must be pressures in the reservoir greater than at the bottom of the well, if there is to be any movement of oil to the well and the average pressure over the field, p will be greater than zero. The exact value of the mean rock pressure when production ceases will probably vary from field to field, depending on the conditions in the oil-bearing formation, and it is doubtful whether anyone at present knows what this value is. Production will cease before p falls to zero and consequently before x reaches the value shown. However, it can be stated definitely that where the oil movement is due to gas energy, with a given gas-oil ratio, the total production cannot exceed the values given.

For fields that have been developed in the past under competitive conditions with little attempt to control the gas-oil ratio, it can be estimated that the mean gas-oil ratio has been between 1,200 and 2,000 cubic feet per barrel, giving values of g between 5 and 6, so that the maximum recovery possible is limited to 16% to 20%. This estimate agrees with those commonly made for the recovery from such fields.

It is evident from this table that the gas-oil ratio should be kept as low as possible in order that the production

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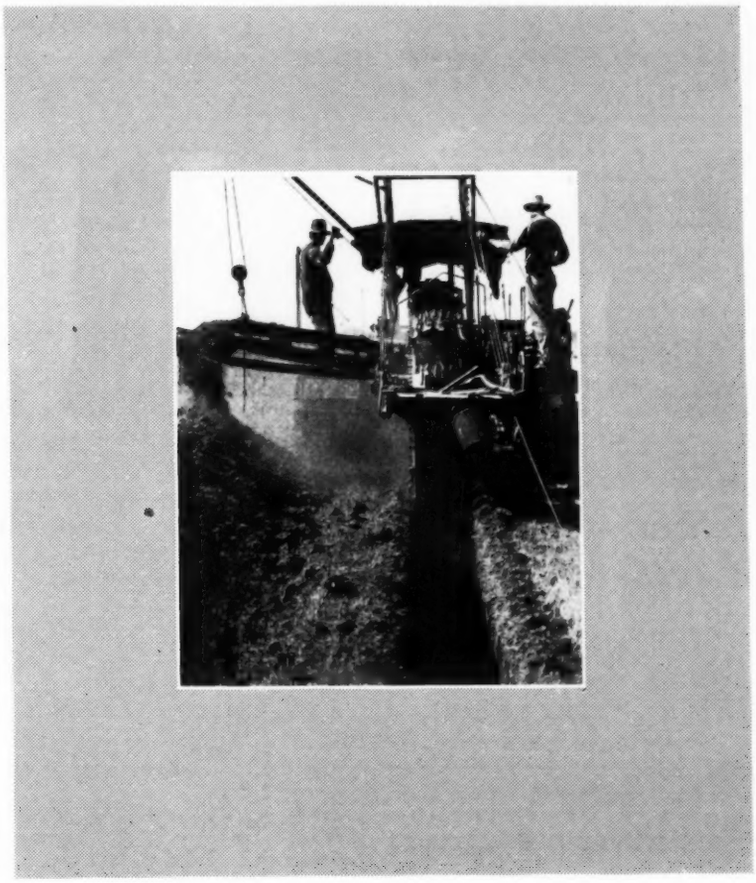

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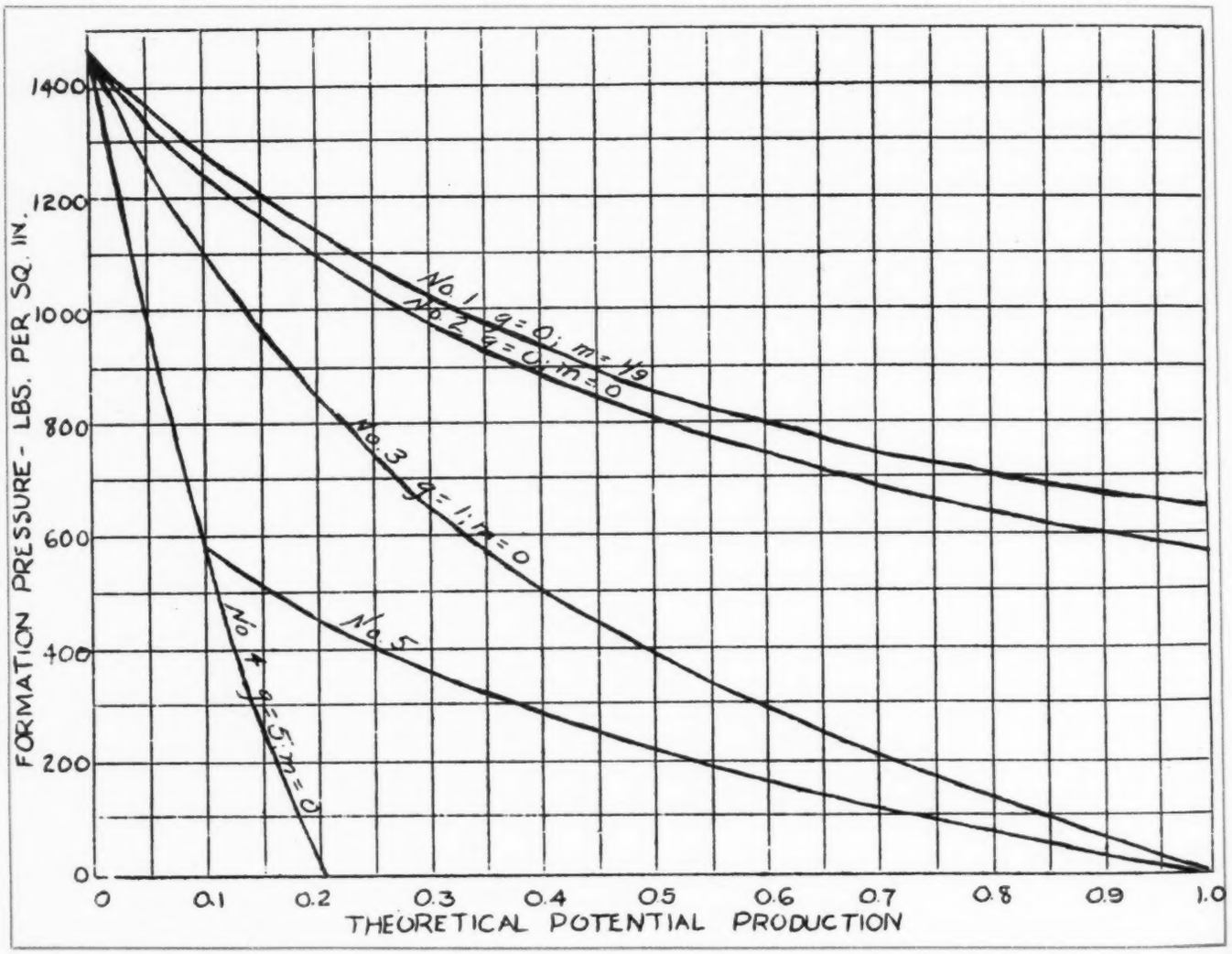
limit may be as large as possible. When the gas-oil ratio is not large, even small changes in the ratio affect the limit considerably. Thus, if the ratio is 480 cubic feet per barrel, the limit is 50%, and an increase of only 240 cubic feet, bringing the total to 720, will reduce the limit from 50% to 33%. In a large pool this can mean a difference of several million barrels. In some fields the ratios can be kept low, but in many the ratios, unfortunately, are high.

In June, 1929, four California fields had average ratios varying between 1,200 and 4,600 cubic feet and one field had an average ratio of 23,000 cubic feet per barrel. Unless an unusually large portion of the reservoir is filled with free gas, these ratios point to a low percentage ultimate recovery. As the crude produced in the field in which the ratio of 23,000 cubic feet per barrel prevails has a high gravity, the solubility of the gas is undoubtedly large. But even if the solubility is as high as 600 cubic feet per barrel under the original pressure conditions and if it be assumed that one-third of the reservoir is filled with free gas, the rock pressure will fall to zero when less than 3% of the oil is produced.

It will be noted from the curves that if, as a result of returning to the reservoir a portion of the gas produced, the value of g is less than 1, p will never fall to zero. This should not be interpreted to mean that 100% of the oil can be recovered. This is not necessarily so, for it will probably happen that as the reservoir becomes depleted, more and more gas will accompany a barrel of oil to the well and as this gas is returned a cycle will be established. Even when under pressure, the daily production rate will probably become quite small as the reservoir approaches complete depletion, so a point will be reached before the reservoir is entirely empty where the rate of oil production is so low that it will not pay to compress the gas necessary to continue production from the field any longer. At what point this economic limit will be reached cannot be predicted, but it seems reasonable to suppose it will be some value between 60% and 80%. This limit is so much greater than those corresponding to normal production methods that it emphasizes the importance of returning all gas possible from the very start.

Although at the present time we are unable to predict how the daily production rate in a particular field will be affected by the mean rock pressure and the extent to which the pore spaces of the sand in the reservoir have been depleted of their liquid content, it is hoped that future research work will reveal such a relation. If anyone is fortunate enough to discover this relation, the equation and the curves described in this paper will be useful in calculating the pressures needed in the expression used for predicting rates of production.

A knowledge of the volume of oil that is contained in a given reservoir is always valuable. If the initial rock pressure, the present average rock pressure, the solubility of the gas and the average gas-oil ratio prevailing up to the present are known, the fraction of the oil which has been produced can be calculated from this equation. If the total oil production up to the present is known, the total amount of oil in the ground can be readily calculated. For example, suppose the original conditions in the field are the same as those assumed in the above illustrations, that the oil is produced with a ratio of 1,200 cubic feet per



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barrel, and that is 2,000,000 barrels of oil have been produced by the time the pressure falls to 1,030 pounds (70 atmospheres). In this case curve No. 4 would apply. According to it, 0.04 of the total amount of the oil originally in the reservoir has been produced, by the time the rock pressure reaches 1,030 pounds; consequently, the total amount of oil originally present is 2,000,000 divided by 0.04 which is 50,000,000 barrels. If by the time the pressure has fallen to 440 pounds (30 atmospheres) the total production is 5,500,000 barrels, this data can serve for another calculation of original amount of oil, which in this case is 46,000,000 barrels. By averaging a number of such calculations made from data taken at various periods in the life of the field, a fairly reliable estimate can be made.

The lack of essential data is the principal obstacle in applying the derived equation in this paper to most of the existing fields. The initial rock pressures were not recorded, the volumes of gas wasted during flush production were not measured, and the relative volumes of free gas and liquid in the reservoir at the start were not determined. The present trend is toward measuring and recording all pertinent data from the very first. The usefulness of this equation emphasizes the need of gathering this data.

Discussion

DR. WILDE prefaced the reading of his paper by stating that rock pressure, as used in the paper, meant the average pressure throughout the reservoir.

Attention was drawn to the use of the equations. An error of 25% in estimating the ratio of gas-filled to oil-filled reservoir, it was explained by Dr. Wilde, would not affect the curve to any extent. By giving "m" too low a value, you would err on the safe side, as it would tend to show you maintained pressure longer than calculated.

In answer to one of the members present, Dr. Wilde stated that the 240-ft. maximum solution was merely an assumed value. For any particular field the gas solubility should be determined. A mixed gas of 88% methane was used.

Mr. Wood found that the introduction of moderate volumes of gas, caused surrounding wells to have an excessive gas-oil ratio, with a resultant decrease in production. Had Dr. Wilde any information on the critical gas-oil ratio?

Dr. Wilde had no specific knowledge in regard to when it ceases to be profitable to reinject gas because of high gas-oil ratios. High pressure repressuring is not necessarily advocated, the paper merely presents equations for aiding in the solution of repressuring problems. If a large amount of oil had been removed from the sand as in Salt Creek, channelling of the gas might take place.

In regard to early repressuring, Mr. Beecher mentioned an instance where repressuring by air, no gas being available, in the newer developed area of a field gave better results with smaller volumes of air than in the older and more depleted area of the same field.

Two Twin Compressor Units For Skelly Plant

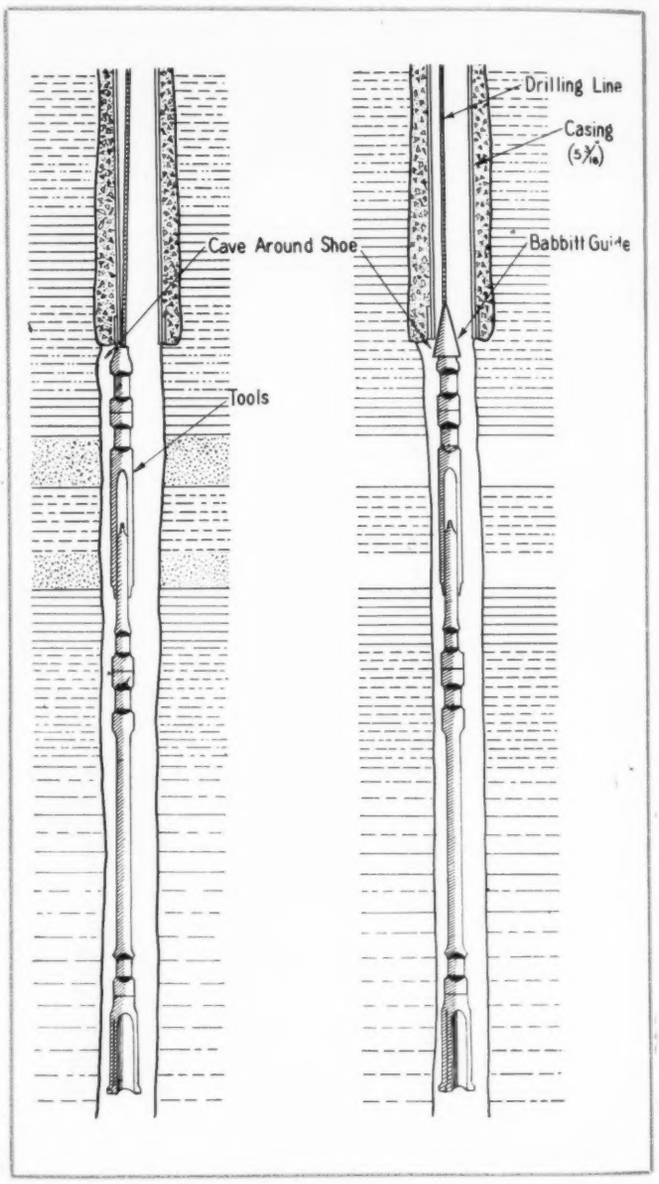
The Skelly Oil Company is building a small gasoline plant in the Asher pool of Petawatomie County, Oklahoma, which will be ready to operate soon, and will have a capacity of 5,000 gallons daily. The plant is the oil absorption type. Two twin compressor units are being installed.

A Fishing Job Forestalled

By J. P. Neel

A STRING of 5⅞-in. casing was landed and cemented in a well at 1,990 feet. When drilling with cable tools below the casing at about 2,047 feet, the formation around the shoe began to cave. At this depth the tools were below the casing shoe and as the hole was not straight, the rope socket hung up on the casing shoe (see sketch).

After working for 24 hours in an unsuccessful attempt to get the tools back into the casing, it was decided to try a simple remedy. A hollow cone-shaped babbitt metal guide was made and sent down on the drilling line (see sketch). A slow motion was then given to the tools. The babbitt



guide directed the tools into the casing and they were pulled to the surface without further trouble.

In this particular well the tools had hung up three times in this manner and on each occasion the babbitt-metal guide was brought into play and worked like a charm. Only one and one-half hours were required to bring the tools safely to the surface the last time the guide was used. The babbitt-metal guide proved a simple but effective tool that prevented what might have been a difficult fishing job.

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Some Observations on

Principles Involved *in* Flowing Oil Wells*

By F. S. SHAW, *Tulsa, Okla.*[1]

THE principles involved in lifting oil in wells flowing naturally are identical with those underlying the flowing of wells by means of the air-gas lift, and information of a dependable nature obtained in the study of the air-lift can be applied to wells with natural flow. A well flowing naturally is one in which the lifting is done by means of the gas-lift, for which the gas is supplied entirely by the formation from which the oil is derived. In air-gas lift operations, there is insufficient gas supplied by the formation to lift the oil to the surface in an efficient manner, therefore additional gas for this purpose must be furnished from an outside source.

There may, at times, be conditions obtaining in natural flowing wells different from those in wells flowed by gas-lift, but these differences do not at all conflict with the main principles of gas-lift work. One such condition is met with in wells in which the gas supplied by the formation is in considerable excess of that required to lift the oil to surface; this excess may be so great as to reduce the quantity of oil that can be lifted through the particular diameter of casing or tubing that has been lowered into the well. This same condition can be brought about, however, by supplying a large excess of gas from an outside source to an artificial gas-lift well, and a study of the effects obtained from injecting a large excess into the well can be applied directly to handling wells flowing naturally which have a large excess of gas supplied by the underground reservoir.

Conditions for Lifting Oil

The main factors to be considered in flowing wells are as follows:

1. Submergence, or pressure at the bottom of the tubing or casing.
2. Lift; the height to which the liquid must be raised.
3. Diameter of the flow tubing or casing.
4. Quantity of liquid to be lifted.
5. Pressure at the discharge end of the flow tubing, or back-pressure, it is sometimes called.
6. Temperature of the liquid.
7. Viscosity of the liquid.

Submergence

In air-lift work, a liquid is lifted by the energy stored in gas under pressure; energy that is given out because the gas expands. If the gas is not under pressure it can do no work, therefore at the lower end of the tubing it must be under a pressure greater than the pressure that exists at the top of the tubing. The measure of the energy is determined by the differences in pressure existing at the bottom and at the top of the tubing, and the pressure to which the gas can be compressed at the lower end of the tubing is determined by the submergence. In other words, the greater the submergence, the greater will be the pressure under which the gas can exist, and the greater will be the work that can be done by a unit quantity of gas. The smaller the quantity of gas containing a given quantity of work, the less will be the friction loss set up by this gas in flowing through the tubing. We have found in practice that the greater the submergence, the greater is the lifting efficiency. In general, we might say that good work is not being done unless the percentage of efficiency is equal to, or greater than, the percentage of submergence.

Lift and Diameter of Tubing

The distance that the fluid is lifted above the existing level of the liquid is called the lift. The work required to lift a unit quantity of liquid varies directly as the lift; that is, to lift a unit quantity of liquid 200 feet will require the expenditure of twice the work that will be required to lift this unit quantity of liquid 100 feet.

Changes in the diameter of the flow tubing will have marked effect on the performance of a gas-lift. In general, we may say that, other conditions remaining the same, increase in diameter of the tubing will permit a greater quantity of liquid to be lifted. However, if there is a given quantity of liquid to be lifted, which cannot be varied at will, there is a given diameter of tubing that will make for the maximum efficiency.

The quantity of liquid to be lifted will determine the diameter of tubing to be used, and will also determine the quantity of gas necessary to lift that given quantity of liquid. Where large diameters of tubing are required, the lifting efficiency will be greater than in wells requiring small diameters of tubing.

Pressure

In general, we may say that the lower the pressure that exists at the discharge end of the tubing, the greater will be the lifting efficiency obtained. Back-pressures are sometimes employed, and sometimes beneficial results are obtained, but probably injurious effects are more often the result. If a well requires that gas be admitted from the compressor in order to lift the liquid, it can almost always be said that back-pressures at the top of the tubing lower the efficiency. A set of conditions may exist, however, in a well flowing naturally, where there is a large excess of gas present with the oil, and where the tubing is of such size that unless a back-pressure is applied at the top there will be an excessive friction loss in passing through the tubing. In such a case, it may be possible that a back-pressure applied at the top will reduce the friction loss and lower the back-pressure at the bottom of the well, and therefore allow a greater quantity of oil to be lifted through the tubing.

Temperature and Viscosity of Liquid

Raising the temperature of the liquid will make the oil thinner, thereby lowering the viscosity and consequently lowering the friction loss of oil passing through the tubing. Instances are known where the heating of the input gas has increased the quantity of liquid being lifted, and this without varying any of the other conditions of operation. It seems possible that the temperature of the oil in the pool may have a marked effect on the facility with which the oil will pass through the sand in reaching the well, possibly in many cases a greater effect than that caused by lowering of the viscosity by high pressures.

*Presented before the Tulsa and Los Angeles meetings of the American Institute of Mining and Metallurgical Engineers, October, 1929.

[1]Consulting Engineer.

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The viscosity of the liquid being lifted appears to have a marked effect, although the direct application of viscosity factors to lifting efficiencies cannot be made at present on account of the almost complete lack of definite information on this subject. The writer once had occasion to lift oil of 22.5° Bé. gravity under conditions that required the expenditure of 2000 cubic feet of gas per barrel; under the same conditions of lift, diameter of pipe, etc., but with oil of 37.5° Bé. gravity, there was required 1100 cubic feet per barrel. So far as the writer was able to ascertain, this great difference in consumption of gas was caused by the difference in viscosity of the oils being lifted.

It may be said in general that, with other conditions remaining unchanged, the quantity of liquid being lifted will vary directly as some function of the submergence and of the diameter of the tubing; and will vary inversely as some function of the lift, of the discharge pressure, and of the viscosity of oil.

Significant Points of Production

In all lifting operations, there are four significant points of production that can be obtained in a tubing of given design, whether that design be efficient or not, as follows:

1. Point of no flow caused by deficiency of gas. This is the point where the amount of gas passing through the tubing is just insufficient to lift liquid, but where, if any more gas be added, a flow will start. In a tapered tubing, 1000 feet long, 7 inches diameter at the bottom and 10 inches at the top, it was found that 1000 cubic feet of air per minute would not lift any liquid, but when the air was increased beyond this quantity the flow of water would start in small quantity.
2. Point of maximum efficiency. This point for any given tubing design is the point which gives the maximum lifting efficiency for any given set of conditions.
3. Point of maximum capacity. For any given set of conditions, there is a definite maximum capacity which it is impossible to exceed.
4. Point of no flow caused by excess of gas. In any given tubing design it is possible to admit so much gas that there will be no flow of liquid. In other words, the friction loss of this excessive quantity of gas passing through the tubing is equal to the submergence pressure.

Control of Gas-Oil Ratio

In a flowing well, the gas-lift factor, or cubic feet of gas required to lift a barrel of oil, is identical with the gas-oil ratio. In artificial gas-lift operations, the gas-oil ratio is the difference between the gas-lift factor and the gas-input factor. The gas-oil ratio may be altered considerably by the quantity of input gas admitted to the well, or, in other words, by the manner in which the well is operated. The gas-oil ratio in artificial gas-lift operations may be controlled within certain limits by any one or more of the following operations:

1. Changing the submergence.
2. Changing the lift.
3. Changing the diameter or design of the flow tubing.
4. Changing the quantity being lifted.
5. Changing the temperature.
6. Changing the pressure at the discharge.

In gas-lift operations it is possible to make changes in any or possibly all of these factors. The most important change lying within the control of the engineer is that of tubing design. In wells flowing naturally, with a given tubing design, change can be made in submergence, in the lift, and in the quantity of liquid being lifted, by use of beans or flow nipples. Changes of tubing design can sometimes be made in wells flowing naturally, though in many cases this change is attended with considerable difficulty, and unless the engineer is practically certain that he knows just what change of tubing will be beneficial, he is reluctant to make any change at all.

Considerable care should be taken to insure correct measurements of gas. Often the flowing of wells under back-pressure causes considerable gas to be carried along dissolved in or occluded with the oil as it goes to the receiving tanks, and as this gas is not measured, incorrect gas-oil ratios may result. Much care should be exercised to insure conditions of gas measurement that shall be similar, or according to similar standards, else comparisons of gas-oil ratios are likely to be confusing and perhaps contradictory.

A careful study of the various factors involved is necessary before the engineer can handle artificial gas-lift operations with any degree of success. This study will be of the greatest benefit when he attempts to handle wells flowing naturally.

Discussion

MR. GRISWOLD stated that in the Wilcox sand wells in Seminole, best results were obtained with minimum pressure at the bottom of the well. Tubing a well does not always restrict the flow. In several instances, tubing relieves the pressure at the bottom of the well, and an increase in production results instead of the flow being restricted. Wells that will not flow through the casing will flow through tubing, because the result of tubing the well is to decrease instead of increase the pressure at the bottom of the well. Conditions that must obtain if oil is properly produced are, maximum rate of oil production, and a minimum gas-oil ratio which should approach the original gas-oil ratio in the sand. This can be done by adjustment of pressure conditions in the well and a knowledge of the well itself.

In contributing to the discussion, Mr. McWilliams made a statement to the effect that the gas can be increased to the point where no increase in production will occur and that the decrease is not due to the increase in gas, but to the condition in the flow string wherein the gas takes the right-of-way, and retards the flow of oil through the tubing.

Dr. Haseman was of the opinion that efficiency in flow by gas-lift will have to be obtained by control of the size of the gas bubble. Since you can not get back into the sand to do this, it must be controlled in the well.

Heavy Demand for New Natural Gas Pipe Line Map

THE widespread interest in natural gas development is indicated by the diversity of requests received for the natural gas pipe line map, recently issued by the United States Bureau of Mines, Department of Commerce. Of the 276 requests for one or more copies received during a recent week, 26 were from engineering firms, consulting engineers and individuals; 27 from oil and gas companies; 51 from banking, investment and insurance companies; 24 from public utility companies engaged in the distribution of natural gas; 19 from trade journals and publishers of statistical analyses; 26 from manufacturers of stoves, valves, meters and other equipment used in connection with natural gas; 12 from chambers of commerce and trade associations; 9 from railroads; 6 from coal and coke companies; 3 from pipe line companies, and 33 from various manufacturing concerns identified as consumers of natural gas. An addition of 1,000 copies of this map, which shows the location of natural gas pipe lines, natural gasoline and carbon black plants, was printed for the Bureau of Mines by the U. S. Geological Survey, and a limited number of copies are still available for distribution.

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The Gum in Gasoline*

By PETER VILKAS *and* L. P. O'NEILL

Producers and Refiners Corporation

IN the presentation of this paper we make no effort to prove or disprove any of the present work that has been done on gums in gasolines. At such an early stage in the investigation of a subject as intricate as this has proved to be, we would be very irrational to state as facts the conclusions we draw from our work. It is our idea to deliver to you our experiences on testing for gums, to give our conclusions for your discussion in order to stimulate an interest and stress the importance of gums that more rsearch will be done on this problem which confronts the refiner, automobile manufacturer and the public more each day.

As long as straight run gasoline predominated as a motor fuel and motor design a low compression ration was used, the problem of gum formation in the motor was negligible and of little importance.

With the continually increasing tendency toward the design of higher compression motors, the production of higher ani-knock gasoline came into importance.

With the production of such gasoline which is usually done by cracking the heavier fraction, the problem of gum also came into importance. Recent development in vapor phase cracking and higher temperatures in liquid phase for the production of the higher anti-knock quality of motor fuel, are usually accompanied with the production of gum forming hydrocarbons. The development of the test for these unstable hydrocarbons is of importance to the manufacturer and distributor of such motor fuels.

Gasoline containing tetra-ethyl lead offers only temporary relief to the automobile manufacturers who are developing higher compression ratio motors, for its use is limited by regulations governing the maximum amount of tetra-ethyl lead that may be added to a motor fuel. With the development of still higher compression motors the use of tetra-ethyl lead as a remedy for detonation is becoming insufficient. So the future for the refiner is to produce motor fuels which themselves possess high anti-knock qualities and the production of such fuels will result in greater quantities of gum forming hydrocarbons being present in the gasoline.

Another new feature in motor design that brings about conditions favorable to "gum" formation in the motors is the elevation of the manifold temperatures to afford the utilization of heavier fuels. Motors operating at higher temperatures have a tendency to form more gums than those operating at lower temperature than the domestic make, experience much more trouble from gumming. The aeroplane motor is another example, the higher temperatures being so conducive to gum formation as to attract government attention to investigate the maximum allowable gum content for use in their air motors.

The refiner of today is confronting the fact that in each new development toward motor perfection, conditions are made more favorable for the production of gums in the motor.

*Presented before Fall meeting Manufacturers' Committee, Western Petroleum Refiners' Assn., Tulsa, Okla.

Interpretation of Tests

At present there are three methods recognized for the determination of gums in gasolines; copper dish test, steam oven test, and the oxygen gum test. The results of these tests do not indicate the amount of gum that will form in the motor while using the gasoline.

The copper dish test, in which a measured quantity of gasoline is evaporated to constant weight, on a steam bath indicates closer than any other method, the sensitivity of the hydrocarbons present, to oxidation. It is, however, open to many variations such as the catalytic effect of copper, the time necessary for evaporation, the quantity of air passing over it due to its current in the room, etc. The results are difficult to check and do not indicate the amount of gum that will form in the motor where oxidizing conditions are entirely different from that in the copper dish. By this method the heavier gasolines show more gum than the lighter ones, which is to be expected, since the rate of evaporation of the heavier gasolines is much lower, so the vapors are subjected to a longer period of oxidation.

In the steam oven test a measured sample of gasoline is poured into a suitable container and evaporated in a steam oven at temperatures approximately from 300° F. to 370° F. This test excludes the oxygen of the air preventing oxidation of the gasoline during its evaporation. When gasolines are tested by this method the resulting gum deposits are almost negligible. Since air is excluded the only gums deposited are those which are formed prior to the test, either during the processing of the gasoline or after its storage. Gum determined in this manner has been referred to as "actual gum" by recent investigators to differentiate between it and the hydrocarbons present, in the gasolines, that can be easily oxidized to form gum. The latter products being termed potential gum. No relation exists between the amount of gum determined in this manner and the amount of gum to be expected in the motor. Recent work by the writers using the steam oven method to determine the gum content of several premium gasolines showed that the actual gum was very small, yet on the gasolines tested, several complaints of their gumming effect in motors had been registered. Also this actual gum being non-volatile would be deposited close to the carburetor and not around the intake valves.

The oxygen gum test is a method recently developed by Voorhees and Eisinger for the determination of both the "actual" and "potential" gum. By their method the gasoline is poured in a long neck boiling flask, the air displaced by a steam of oxygen, the flask closed with a rubber stopper, and oxidation allowed to take place for five hours at the temperature of boiling water. The oxidized gasoline is then transferred to an evaporating dish, and evaporated in a steam oven. The technique of using a rubber stopper to close the boiling flask during oxidation, is questionable. It was the experience of the writers during their first use of this method to obtain results that apparently were too high and these could not be checked with the desired degree of accuracy. However, when carefully selected corks were used in place of the rubber stoppers this difficulty was over-

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come. It seems that the vapors of the gasoline in constant contact with the rubber during the oxidation period dissolves a part of the rubber, and on evaporation of the gasoline the rubber is deposited with the gums formed.

It can hardly be said that the oxygen gum test is a measure of the stability of the hydrocarbons present in gasoline. Two different gasolines may show the same amount of gum by this test, however the oxidation that produced the gum in one gasoline, may have been completed in the first thirty minutes of the test while the reaction in the second sample may not be completed at the period of five hours. The observation on a large number of gasoline samples during oxidation offered interesting results. Some gasolines oxidize in the first hour, forming nearly all of the potential gum that can be formed under those conditions, the further oxidation brings only a very slight increase in potential gum. Other gasolines give hardly any noticeable amount during the first hour of oxidation, and the rate of oxidation increased with time.

Although both samples show the same amount of potential gum, the first consists of unstable hydrocarbons, which oxidize in a short period in storage or in the motor, while latter sample would probably remain in storage for a long period without appreciable formation of gum. The same gasoline may deposit gum in one motor and will not deposit in the other depending on the operating temperature of the motor. But the gum once started to deposit will continue depositing even using more stable gasolines for the gum has attraction for the peroxides that are formed in the manifold. The first deposition starts when, after using an unstable gasoline, the motor is not in operation, these oxides left in the manifold condense and polymerize, thus depositing the initial gum. On second operation the deposition of gum will take place even during the operation.

Gums Are Products of Oxidation

What is referred to as gum in gasoline is recognized generally as the resinous mass, amorphous in structure, non-volatile, found in the carburetor and intake manifold of the motor, or left in a dish after evaporation of gasoline. The chemistry of the reaction which brings the gum formation from the unsaturated products in the gasoline is little understood, however what work has been done is in fair agreement with respect to the initial reaction in which the oxidation of the more sensitive hydrocarbons takes place. The mechanism of the oxidation, probably due to its complexity, has received little attention from the investigators. The probable assumption is that the unstable hydrocarbons unite with atmospheric oxygen forming peroxides and the gum is the product of the polymerization of these peroxides. That the oxygen is the important factor in gum formation is indicated by the following test. The samples of gasoline were evaporated in atmosphere of steam, with air completely excluded, gave identically the same results in glass and copper dishes, neither temperature nor time element came into consideration. While on the other hand the samples evaporated in air atmosphere gave higher gum values depending on temperature, the time of exposure and the catalytic effect of copper dish.

The following results were obtained in the sample of a regular grade of low gum gasoline:

Description of Test	Mg. per 100 cc.
Steam oven test in glass dish	1.5
Steam oven test in copper dish	1.5
Oxygen gum test	2.0
Steam bath air atmosphere in glass	2.0
Steam bath air atmosphere in copper dish	3.5
Electric oven at 300° F. glass dish	42.0
Electric oven at 300° F. copper dish	197.0
Oxygen test using rubber stopper during oxidation	25.0

Another test was made on for samples of premium grade of gasoline using the various methods, the following results were obtained.

Sample No.	Steam Oven Test	Oxygen Gum Test	Electric at 175°F.	Oven in Air at 250°F.	Atmosphere at 350°F.
1	1.2	3.0	6.8	183	18.1
2	1.5	13.6	8.0	370	24.1
3	1.3	54.0	10.4	274	16.2
4	4.2	42.0	14.0	137	27.8

From the results one readily can see that there is no limit to gum formation. The higher are the temperatures, the more gum is formed, although evaporating dish may not show all in the residue. The non-volatile residue indicates only the oxidation of products that have been polymerized during the test. The oxidation products which are not polymerized passes out with the gasoline vapors. These unpolymerized oxides are non-injurious to the motor, they pass into combustion chamber with the rest of the gasoline vapors. In vapor state they do not readily polymerize, for they are defused among other gases and do not combine to form a solid mass. They are not attracted by metals, but the gums have an affinity for these peroxides. We have suspended various metals in gasoline vapor and air mixtures and no deposit was noticed on any of these metals, but if a metal coated with a small amount of gum was exposed to these vapors, a noticeable deposition of gum occurred. The reason that these oxides exist in vapor state is proven by collecting these gasoline vapor and air mixtures and absorbing in gum free gasoline, thus giving a chance to come in contact and polymerize, on evaporating in steam oven the gum is deposited in the dish.

It is reasonable to suppose that as long as the motor is free from gum deposits no gum should be deposited during the operation, but when motor is not in operation the peroxides left in the manifold on standing will deposit gum.

On next operation the oxides will be attracted by the gum and the deposition will be accelerated by the increase of the gum present.

We have devised a method for measuring the resistance to oxidation of the unsaturated hydrocarbons, or in other words the stability of the unsaturated hydrocarbons in the gasoline. The method consists of passing the gasoline vapor and air mixtures through a tube corresponding to an intake manifold, which is kept at approximate intake manifold temperature, absorbing vapors in gum, free gasoline evaporating the gasoline in steam oven and weighing the residue. No gum deposit was noticed in the tube, but on evaporation the absorbed vapors gave good indications as to stability of the gasoline.

The work on this method is not completed, and it has to be supplemented with actual motor test, before the conclusion can be drawn as to the amount of permissible gum in the gasoline before it would affect the operation of the motor.

In conclusion, it may be said that the gum problem is not yet solved, although it is getting more important every day. The future manufacturers of the anti-knock gasolines have to study the cracking conditions so as to prevent the production of the unstable hydrocarbons, and also develop the test for measuring the stability of these hydrocarbons.

Spacing of Wells in the Long Beach Field*

By DWIGHT C. ROBERTS *and* STENDER SWEENEY

I. PURPOSE

A GREAT amount of discussion concerning the spacing of wells in Long Beach Oil Field has taken place from the earliest days of its development up to the present time. This discussion has been brought about by the closely drilled town-lot areas which have been as intensively developed as any productive areas in the world. It is, therefore, the purpose of this paper to present the results which have been obtained from this type of development compared to the more widely spaced development in this field now that a sufficient length of productive life has elapsed. An idea of the intensity of development in Long Beach is given when one considers the fact that up to September 1, 1929, there were 1,736 wells either drilled or drilling. Of these 165 failed to get production and 121 were drilling. Thus 1,450 wells have produced oil from an area of 1,350 acres. Up to July 1, 1929, these wells produced a total of 355,047,913 barrels.

II. DESCRIPTION OF METHOD PURSUED

Four groups of offset areas were chosen; in each group the wells in one area are widely spaced and in the other, closely. The areas in each group are contiguous and the groups are spread over the field from the southeast end to the northwest so that representative data are assured. The comparison has also been divided into shallow and deep zones and like zones in their respective areas compared.

It is thus believed that, even though these productive zones are of great thickness, a fair picture of results is obtained due to the fact that the drilling of the wells in the two types of areas was concurrent in the different groups and, as a rule, the thickness of sand opened up at any one time was about the same. As deeper sands were found, wells in offset areas were either deepened or new ones drilled in both types of areas. The basis of division of zones was made in the same manner in contiguous areas.

The total cumulative production up to July 1, 1929, of the wells in their respective zones in each area was obtained. From these figures were computed the recovery per well, recovery per acre, acreage per well, and the ratios of these factors. Thus, July 1, 1929, is the end of the period considered in all areas.

III. DATA ON AREAS

Areas A and A'—Shallow Zone

These areas consist of seventy acres each, one of which has been drilled on a more widely spaced program and the other very closely. These wells have been producing about six years.

	No. Wells	Total Recovery	Recovery per Well	Recovery per Acre
A	24	6,397,665 bbls.	266,569 bbls.	91,395 bbls.
A'	98	13,759,127 bbls.	140,399 bbls.	196,558 bbls.

In area A the average acreage per well is 2.92, while in A' it is 0.71. Thus it is apparent that the recovery per well has been greater in the more widely spaced area while the recovery per acre, and consequently the total recovery, has been greater in the closely drilled area. The following proportions between these factors have been computed:

Ratio of Acreage per Well, A' to A—1:4.08.
Ratio of Recovery per Acre, A to A'—1:2.15.
Ratio of Recovery per Well, A' to A—1:1.89.

This shows that four times as many wells have been drilled in A' as in A. The recovery per acre has been more than twice as great in the closely drilled area while the recovery per well has been slightly less than half as much.

Areas B and B'—Deep Zone

These consist of 20 acres each. This development has taken place during the last year and a half. B is the wider spacing and B' the town-lot.

	No. Wells	Total Recovery	Recovery per Well	Recovery per Acre
B	6	1,399,827 bbls.	231,638 bbls.	69,990 bbls.
B'	24	5,471,061 bbls.	227,961 bbls.	273,553 bbls.

In area B the average acreage per well is 3.33, while in B' it is 0.83. Thus there have been four times as many wells drilled in B' as in B.

Up to the present time the wells in each area show an average recovery per well of about the same amount.

Ratio of Acreage per Well, B' to B—1:4.
Ratio of Recovery per Acre, B to B'—1:3.98.
Ratio of Recovery per Well, B' to B—1:1.02.

Four times as many deep zone wells here have produced practically four times the amount of oil, but it must be borne in mind that the elapsed life of this production has been short and nearly all the wells are still in the flowing stage.

Areas C and C'—Shallow Zone

These two areas also consist of 20 acres each, C being the wider spaced. Production has been obtained from this zone in these areas for almost seven years. Nearly all the development took place during their early life.

	No. Wells	Total Recovery	Recovery per Well	Recovery per Acre
C	6	2,824,113 bbls.	470,685 bbls.	141,206 bbls.
C'	23	3,621,756 bbls.	157,468 bbls.	181,088 bbls.

In area C the average acreage per well is 3.33. The productive life of these wells has been great enough to give a very fair basis of comparison of two offset areas which are well along in the pumping stage on similar positions structurally, but developed on a radically different drilling program.

Ratio of Acreage per Well, C' to C—1:3.83.
Ratio of Recovery per Acre, C to C'—1:1.28.
Ratio of Recovery per Well, C' to C—1:2.99.

Thus, somewhat less than four times as many wells have obtained about one-quarter more oil. However, the recovery per well has been three times as great on wider spacing with the attendant greater return per dollar invested.

Areas C and C'—Deep Zone

These are the same areas considered in the preceding discussion, but attention is directed toward the results of deep

*Presented before the Los Angeles meeting of the American Institute of Mining and Metallurgical Engineers, October, 1929.

zone drilling which started a little short of two years ago and continued concurrently in both areas.

	No. Wells	Total Recovery	Recovery per Well	Recovery per Acre
C	8	1,655,407 bbls.	206,926 bbls.	82,770 bbls.
C'	20	2,760,981 bbls.	138,050 bbls.	138,050 bbls.

In area C the average acreage per well is 2.5 while in C' it is 1.0.

Even though these wells are in the earlier stage of their lives many have been on the pump or compressor for some time. Neither of these areas gives promise of reaching the production obtained from shallow zone wells in these same areas.

Ratio of Acreage per Well, C' to C—1:2.5.
Ratio of Recovery per Acre, C to C'—1:1.43.
Ratio of Recovery per Well, C' to C—1:1.67.

The wells drilled for the deep zone in the C area were more closely spaced than wells drilled for the shallow zone in the same area. At this period of their lives the deep wells show a greater proportionate recovery per acre than they do per well as compared to the shallow zone wells of this same area.

Areas D and D'—Deep Zone

These areas comprise 15 acres each, on which only deep zone production is compared here. The productive life considered has been about one year.

	No. Wells	Total Recovery	Recovery per Well	Recovery per Acre
D	5	737,020 bbls.	147,404 bbls.	49,135 bbls.
D'	17	2,335,581 bbls.	137,387 bbls.	155,705 bbls.

The average acreage per well in D is 3.0 and in D' it is 0.88. Development in this area is more recent and consequently the productive life to date, shorter than in any other comparison which has been made.

Ratio of Acreage per Well, D' to D—1:3.4.
Ratio of Recovery per Acre, D to D'—1:3.17.
Ratio of Recovery per Well, D' to D—1:1.07.

These wells are practically all still flowing. They show over three times the production per acre from D' as from D up to the date considered. Their recovery per acre surpasses that of D so that it is certain that with the present wells it will not reach the closely drilled area in this respect.

IV. CONCLUSION

Due to the size and shape of the areas chosen, their similarity geologically within each group, and their location in widely separated parts of the field, it is felt that the above are representative comparisons and therefore legitimate to use for a few general conclusions.

In no case has the recovery per acre in wider spaced areas reached the recovery per acre in closely drilled areas. The difference between them is greatest during the early life and tends to decrease during the later years. This contention is further supported by noting the way which wells in both types of development produce about the same amount per well during the flowing, or flush, stage which fact necessarily gives a greater acreage recovery during that period. B-B' and D-D' support this statement, whereas C-C' recovery per well shows considerable favor for the wider spaced area in the deep zone at present. However, this fact may be explained by the performance of the wells which have not had a very long flowing life, so that a fair portion of the oil recovered has been derived after that period.

It is apparent that a greater yield of oil will be obtained from an area closely drilled than from a similar one with wide spacing. However, the economic return on the investment then becomes the governing factor to determine whether, under current market conditions, such additional expenditure is justified.

The conclusions drawn in this paper are taken from a study of a field of very great thickness of oil sands of great productivity. They should not be considered as applicable to one of a single, thin sand. It is, however, believed that they will be of use in fields of a similar nature to Long Beach.

The Arab Gasoline Corp.'s research laboratory and staff at Eastland, Texas. T. S. Bacon, director of research, standing at left, and J. E. Bludworth, research chemist, holding the burette.

University Course on Oil Industry Started at N. Y. U.

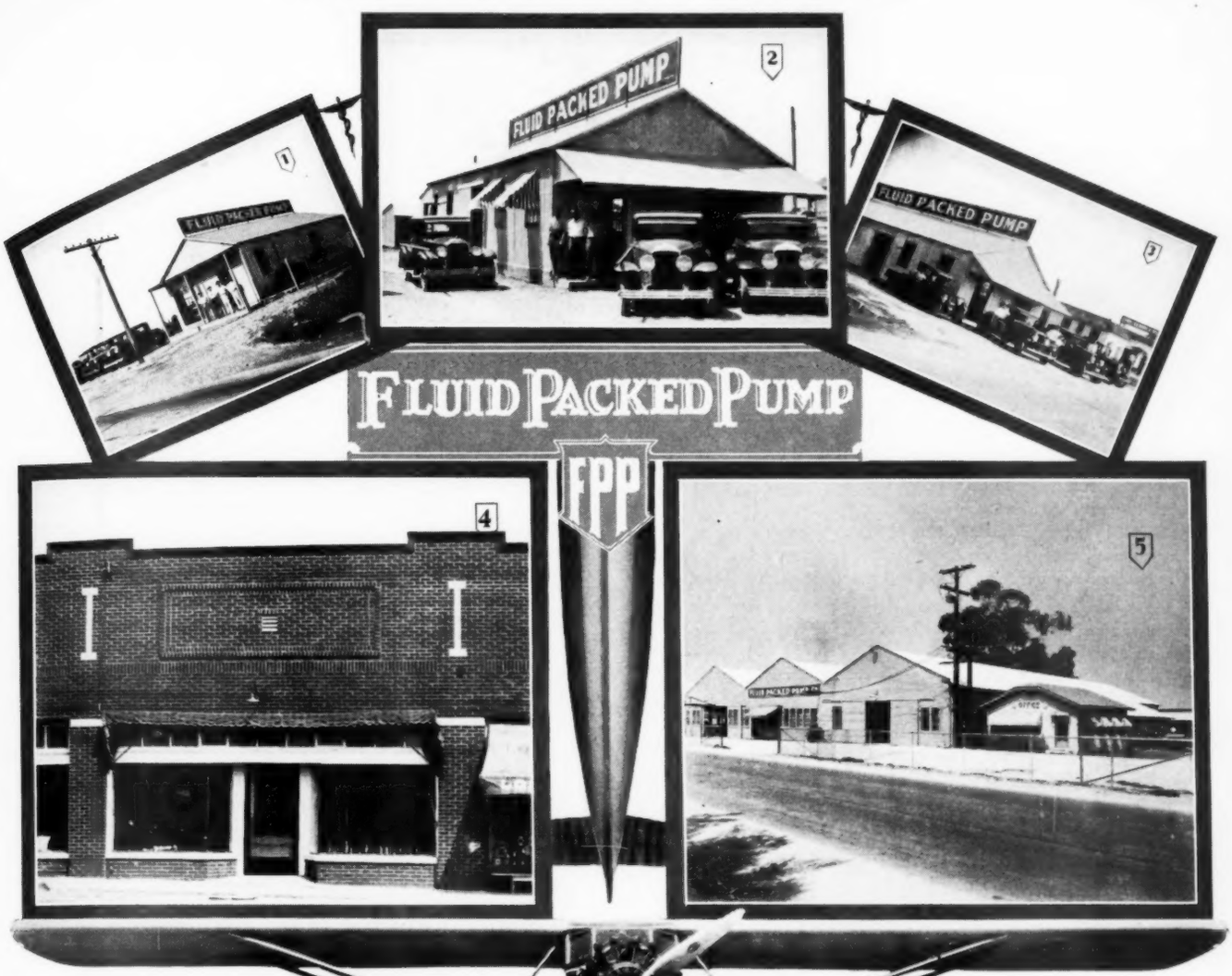
FULL year courses on the oil industry have been started at New York University's School of Commerce, Accounts and Finance under the direction of Dr. Ernest R. Lilley, author of "The Oil Industry," "The Geology of Petroleum and Natural Gas" and other books.

One course, known as "The Oil Industry and Oil Company Operations," is designed for those who are actually engaged in this field, but is helpful also to those who desire to keep up with current movements in the industry.

The second course, "The Marketing and Utilization of Oil Products," is designed for those actually engaged in the oil industry and those who in the judgment of the instructor can contribute to the discussions.

Dynamometer Test on Refined Shale Oil Gasoline

A DYNAMOMETER test on refined shale oil gasoline was recently made by the United States Bureau of Mines in co-operation with the State of Colorado, at the University of Colorado. The gasoline used in this experiment was refined by low temperature sulphuric acid treatment. The analysis of the treated gasoline was as follows: A. P. I. gravity, 58; Doctor test, sweet; color, 25 Saybolt; sulphur, 0.111%; Engler distillation, satisfactory; unsaturation, about 20%. The dynamometer was a six-cylinder engine used by the University in the automobile testing laboratory. After running the engine on a standard gasoline to insure constant operating conditions, a series of tests was made on the shale gasoline, and the electrical horsepower developed was 30.43 which was an increase of 4.03% in horsepower over the petroleum gasoline.



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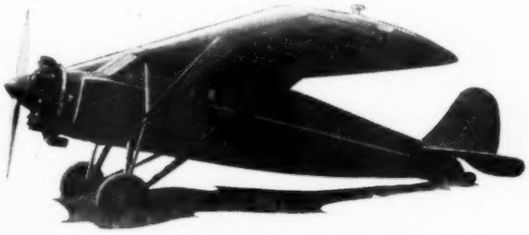

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Application of Vacuum Distillation to The Production *of* Lubricating Oils*

By **EARL PETTY,**
Smith Engineering Co., (Pa.)

FOR a number of years the application of vacuum distillation to the production of lubricating oils has attracted the attention of the refinery technologist and the equipment manufacturers. However, it is only within the past year or two that the refiner himself has become interested. The tardy development of this interesting process may be attributed to the lack of proper appreciation of the refiners problems on the part of many of the equipment manufacturers and also to the market conditions. During the past few years the decrease in the amount of green crude available as compared to market demands in the mid-continent area, the desire for decreased operating costs, and the ever increasing demand for oils of high physical properties has focused the attention of the refiner on this subject.

This process has interesting possibilities for every manufacturer of lubricating oils, whether he is processing paraffine base oils or asphalt base oils or the so-called mixed base crudes. Naturally, the procedure for handling these rather distinct crudes differs somewhat. In this discussion we are pre-supposing the use of pipe stills provided with efficient fractionating equipment and it might be well to comment that the development of this combination equipment has been a vital step in bringing the present systems of vacuum distillation into such prominence and favor.

(A typical arrangement of such unit is shown by flow sheet No. 1.)

The general plant arrangement and method of operation follows:

A reduced crude representing approximately from 40 to 50% of the whole crude is pumped through a system of heat-exchangers to the pipe still, where it is heated to the temperature to vaporize the desired distillate products.

Gear care should be taken in the design of the pipe still so that the temperature of the oil film next to the tube wall is held within a very few degrees of the average temperature of the oil stream. Otherwise the purpose of the system of operation will be defeated. After leaving the pipe still the hot reduced crude is flashed into the vaporizer section of the fractionating column in the presence of steam. The vaporized portion ascends the rectifier section of the tower where it is counter-currently contacted with reflux supplied at the top of the column, thus removing the undesirable heavy asphaltic materials of higher boiling range. The overhead vapors enter a tubular condensing system, so designed as to condense the oil in two portions. The separation realized by fractional condensation is usually sufficiently close for the products being handled. The more viscous lubricating stocks are taken as side drawn streams. Only one stream is taken where paraffin crudes are being handled but two or more such streams may be taken when asphaltic oils are being distilled. The asphaltic bottoms are counter currently stripped with super-heated steam in the stripping section of the tower.

Where paraffin base crudes are being processed, the light ends down to and including part of the gas oil are removed by steam-atmospheric topping units and the reduced crude, containing the wax distillate, the highly viscous fractions, and the tar, is charged directly to the vacuum pipe still and flash vaporized in the vaporizer section of the tower. The wax distillate and the high viscosity stock are vaporized and pass upward into the rectifying section of the tower where they are closely fractionated by virtue of being passed counter flow to wax distillate reflux which is pumped in at the top of the tower over the fractionating plate and bubble cap system.

The wax distillate passes from the top of the column in the vapor form and the vacuum refined stock is taken a side drawn product.

The unvaporized bottoms, along with the high boiling range liquid from the rectifying section flow down through the stripping section in counter flow to the superheated steam introduced at the bottom of this section, thus removing the last traces of the valuable viscous oil materials and at the same time lowering the vaporizer temperature required to vaporize the stocks and wax distillate.

The wax distillate, as handled above, is directly pressable without further processing or redistilling and can be produced in practically any viscosity desired by manipulation of the amount of gas oil removed by partial condensation. When handling pure paraffin or mixed base crude and making a vacuum refined stock of from 150 to 160 vis. at 210° F. as a side drawn product, the end point of the whole wax distillate cut will not be too high and will not carry inhibiting materials which will prevent pressing. It has been demonstrated in commercial units that this material can be pressed in viscosity range as high as 120 sec. at 100.

Determination of the vis. of the pressing stock is made by the following conditions:

The lower the viscosity the higher the rate of filtration or pressing but entails a liquid burden of gas oil which makes a fluid burden for equipment, added refrigeration and redistillation plant load.

The higher the vis. of the wax distillate the lower the filter press rate, but reduces refrigeration requirements, gives higher yield of viscosity material from material chilled and pressed and requires less redistillation capacity. If a plant has limited filter press capacity but plenty of refrigeration, then a low vis. wax distillate would be most practical. If a plant has excess filter press capacity but limited refrigeration a more viscous material might be pressed.

A definite trend is to make a more viscous wax distillate, viz., 80-90 vis. for straight pressing and also to make even a 100-120 vis. stock and then dilute with a less viscous material such as nap. or light gas oil to reduce viscosity and increase flow rate through presses, but at the same time bring in the minimum fluid burden.

The viscosity of the vacuum refined overhead stock may be varied in viscosity from 90 sec. viscosity at 210 to 160 viscosity at 210. Through this range the stock can be readily dewaxed by the centrifuge, filter-aid or selective solvent method. The plan of dewaxing a whole heavy lub overhead stock similar in range of viscosity to long residuum is much more easily carried out than on long residuum stock. The viscosity of the stock to be processed

*Presented before the Fall meeting Manufacturers' Committee, Western Petroleum Refiners' Assn., Tulsa, Okla.

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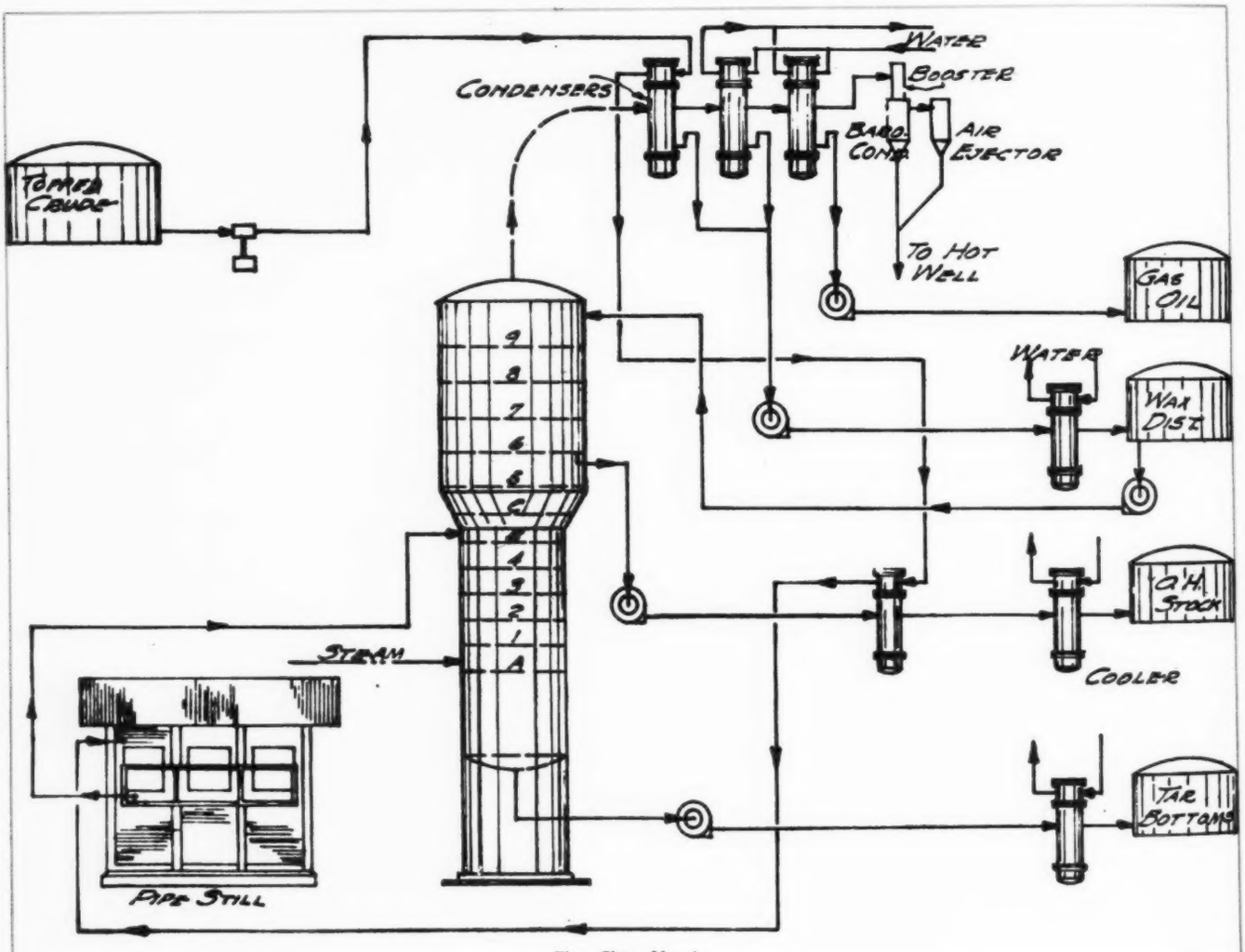
is determined by the equipment available and the products which it is desired to produce. For example, it has been found in the production of zero cold test motor oils, a neutral and bright stock can be made from a stock from 90 to 110 viscosity at 210 most economically. The determination of the viscosity of the material to be dewaxed by combination pressing and centrifuging revolves around the capacity balance of the equipment available, the value of light non-viscous neutrals. This will determine the relative cost of the two methods. By centrifuging a 90 viscosity vacuum refined stock the dewaxed material can be broken up into a heavy neutral and a conventional bright stock by means of a rerun unit, and by this method all the 300 viscosity or even the 250 vis. (at 100° F.) netural will have been dewaxed by the centrifuge operation. This leaves all the lower viscosity wax distillate to be pressed or charged to cracking material. If a whole wax distillate is pressed for 300 viscosity neutral only, and the total cost of the operation charged to this single material, it will make the pressing cost higher than that of centrifuging in a long vacuum refined overhead. Needless to say, it is impossible to centrifuge a 300 viscosity wax distillate alone but a material similar to the conventional long residuum can be centrifuged. In Europe in 1923 the writer successfully centrifuged on full scale size operation an 80 viscosity overhead stock made on B.K.M. (Brunen Koenigsfelder Machinenfabrik) equipment. This product was made on a battery of continuous stills which were operated with only partial condensing-fractionating equipment under absolute pressure of 45 to 65 m/m of hg. Since that time I have had great enthusiasm for the process of dewaxing overhead stocks and we are just about to see the acceptance of the method in this country by the use of equipment which offer every reason for giving improved results.

By the filter-aid method which is just now being given new life due to certain process details and improvements, and due to the backwardness of centrifugal engineers to tackle the dewaxing of these overhead stocks, especially the longer cuts, an entirely new problem on the economics of dewaxing is facing us. It offers the advantage of being a little less critical of control as to nature of stock being handled, less dilution is required, less delicate chilling process, less refrigeration due to less diluting material and closer gap of cold test and temperature. Its handicaps are that it involves more process and mechanical details. Solvent methods of dewaxing are always being demonstrated on a commercial basis independent of filter-aid process and centrifuge process.

Regardless of dewaxing process the overhead stock as produced by this method is a narrow range boiling material which has been fractionated under conditions which prevent cracking and it possesses physical characteristics decidedly different from those of a residual product. The initial boiling point may be rather closely regulated and there are sufficient plates to produce a closely fractionated product, passing all coloring matter or asphalts of higher boiling range into the pitch drawn from the base of the tower. By this method we obtain a maximum flash-viscosity relationship and extremely light colors. Stocks prepared in this equipment usually have from 30 to 50° F. higher flash for a



Flow Sheet No. 1.

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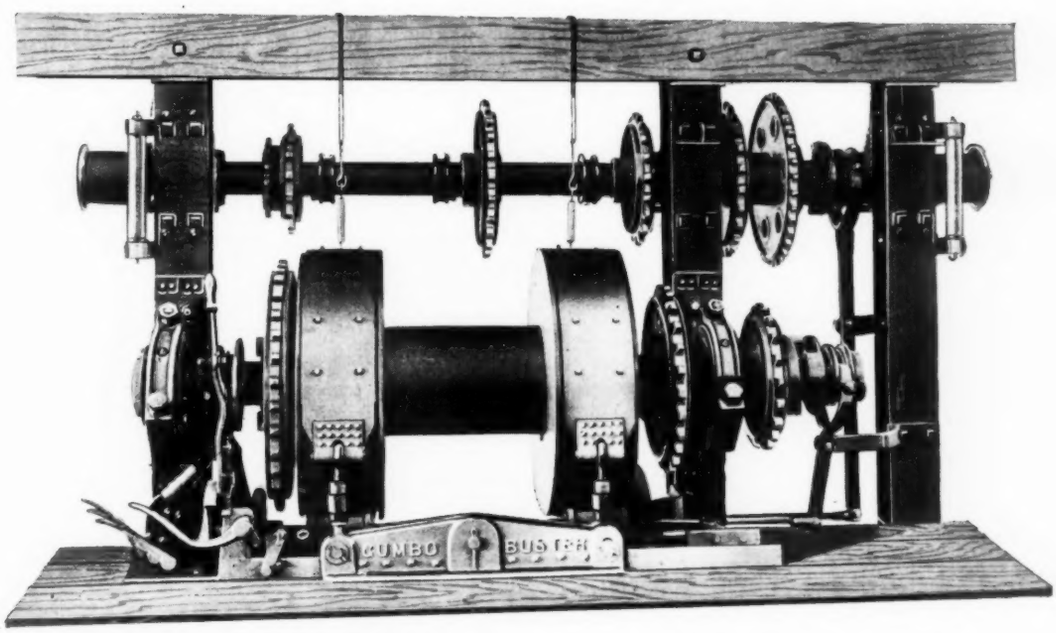

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4. Cat Line Rollers are extra large in diameter and operate on roller bearings.
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given viscosity than a residual stock produced from the same crude. The color of the material directly off the tower will be found to be practically the same as that of a well treated residue stock after being processed with from 35 to 40 lbs. of acid per barrel by the conventional treating method. It will be noted, of course, that this vacuum refined stock will have considerably higher cold test than even the acid treated stock. This does not mean that a larger per cent of wax is segregated into this cut but indicates that the waxes are not dissolved or hidden in excessive inhibiting coloring material. It will be found that the cold test is more nearly the same as that of an acid treated and filtered residual stock. The vacuum refined overhead stock carried a balance between coloring matter and the higher boiling waxes in such a form that the wax is free to be precipitated by normal temperature effect as is indicated by the high cold test of the product, this ranging from 75 to 100° F. This is due to the fact that this carefully fractionated material carries no high boiling coloring matter or asphalt, or coloring matter which has been rearranged into lower boiling ranges by the cracking and by catalytic effect of asphaltic materials in the pitch at elevated temperature. These materials exert a colloidal solvent effect on waxes, making it impossible to dewax by mechanical means.

Asphalt Base Crudes

It is rather difficult to outline a definite procedure for handling asphaltic base oils as it is dependent to such an extent upon the characteristics of the crude itself. When paraffin oils are being processed it is a constant fight to recover as many viscous units as possible but in the case of asphaltic base oils the real battle is to obtain a good flash for and lower the viscosity.

Due to the absence of waxes and the excessive amounts of coloring and unstable materials the problems become that of distillation, fractionation and acid treating. The simplest procedure is to reduce the crude in a separate topping still and then charge to the vacuum unit, where it is fractionated directly into two or three separate cuts such as a neutral, a motor oil, and a bright stock, residuing the pitch material. Each of these cuts must be refined or treated separately to make marketable products. This brings in a complication in tower design where so many side streams are drawn due to plates required and the attendant pressure drop, making it necessary to operate the vaporizer section of the tower at a higher pressure than when making only one side drawn material. This, of course, raises the temperature condition. Recent work carried out in Germany indicates that stocks distilled at too high a temperature in the presence of their asphaltic materials suffers some decomposition due to the catalytic action of the asphalt. The other alternate of distillation is to charge the reduced crude to a vacuum unit similar to that used on paraffin base oils and make a total lube cut similar to the total wax-lube cut and then treat as a whole unit following with a rerun unit to make the required fractionation. This offers the disadvantage of there being a possibility of following even this last distillation by some treatment for final stability.

Results Summary

As indicated above vacuum distillation coupled with fractionation offers many interesting features. The trend of vacuum distillation today is so closely coupled with fractionation that it is difficult to decide which to give the most credit. Personally, I think the fractionation equipment has put the process over. But the combination explains the progress being made, whereas vacuum distillation as previously known had made little progress.

For the credit of fractionation the following stock gives an example: A Penna. topped crude was charged to a vacuum unit and gas oil and wax distillate taken overhead. A side stream of 65 vis. at 210° F. 505 flash was taken and centrifuged. This left a residue stock of 152 vis. at 210° F. with 590° flash. Similar stocks made by conventional methods without fractionation were of 450 flash for the 65 vis. and 540 flash for the 150 vis.

Another example may be found in a Louisiana crude fraction of 65 vis. at 210, 635 at 100° F. with a flash of 430° F.

Take the case of Black Mid-Continent crudes as a source of raw material, using for example Seminole or Kansas crude, approximately 13% of 520 flash 150 vis. vacuum refined stock can be made or 10% of 540° F. flash, 150 vis. or 8% of 560 flash, 150 vis. can be obtained.

To finish bright stock from 7-8 nap, the vac. ref. stock will require from 6 to 8 pounds of 66 comml. H_2SO_4 per bbl. and require slight straining of 4 to 6 pounds of clay per bbl. for neutralization and de-blooming.

To finish bright stock of 5-6 nap from 20 to 24 pounds of acid will be required from 4-6 pounds of clay per bbl. for neutralizing and de-blooming.

Wish to explain that the above-mentioned quantity of clay is required for neutralization only and when put on an acid oil that has been treated by the centrifugal method of separating sludge there is no pepper to remove and to accomplish the neutralization only slight heating is required to cause a further break between the oil and any dissolved acid that remains. This gives further decolorization but the primary use is in the neutralization.

It is readily seen that with the general application of vacuum distillation vacuum refined stocks will be obtainable from all black crude bottoms, and this new product will be of equal or better characteristics than our present treated s. r. stocks from green crudes. This might immediately be interpreted to indicate that the advent of vacuum distillation means the same thing in the lube industry that cracking did to the gasoline business 10 years ago. However, there is another side to the picture and that is that the factor of improving quality and disregarding yields is most appealing to all of us and in reality vacuum distillation may bring us to such high standards of viscosity, boiling ranges and flash characteristics that our yields from black grade crude will be less than by the present system and if this should be the trend, with our ever increasing demand for lube oils of higher viscosity units, we may have to run a greatly increased amount of crude in order to get the fractions required for lubricating stocks, and discard the light ends for cracking materials.

Another trend will be to make new surveys and evaluations of various crudes from different sections of the country and process them by this new method and find what special fractions may be had for lubes by utilizing these modern units.

With vacuum distillation coupled with fractionation equipment applied to Gulf Coastal crudes an entirely new source of lubes of new and surprising characteristics are found. The same is true of West Texas and Mid-Continent crudes.

Over all I think the various processes and phazes of our lube industry has been more conservative about making changes in methods, equipment and process than has the light oil end of the industry. For ten years now the lube industry has been diligently studying these new possibilities. Vacuum distillation as reality has not bursted out on us as a thunderbolt from a clear sky but has bent through all our major laboratories and research departments and finally a fairly well co-ordinated system and hook-up of departments has been worked out correlating the various steps and phazes necessary for making a full line of finished materials from any crude using vacuum distillation for both primary and secondary fractionations.

Sun Oil Company Instrumental in the Development of

Gyroscopic Instrument *for* Surveying Wells

By S. H. WILLISTON

THE petroleum industry has recently become cognizant of the financial importance of crooked holes. Many, if not most, of the major producing companies are at present measuring in some manner or another the inclinations of their wells and are doing all that they are able in an endeavor to keep their wells vertical or at small inclinations from the vertical; but in many cases in spite of their best endeavors the wells are not straight and it has become increasingly important from the point of view of both the geologist and the petroleum engineer that accurate information as to location of the bottom of the hole be obtained. The geologist bases his sub-surface maps upon logs and samples of the drilled wells, and unless he knows the true location of the formations his work is in error and its value is seriously depreciated and may become worthless. The petroleum engineer must know the location of the producing well in the sand for without that information it is impossible for him to space properly the wells so that he may obtain the maximum drainage of a given area.

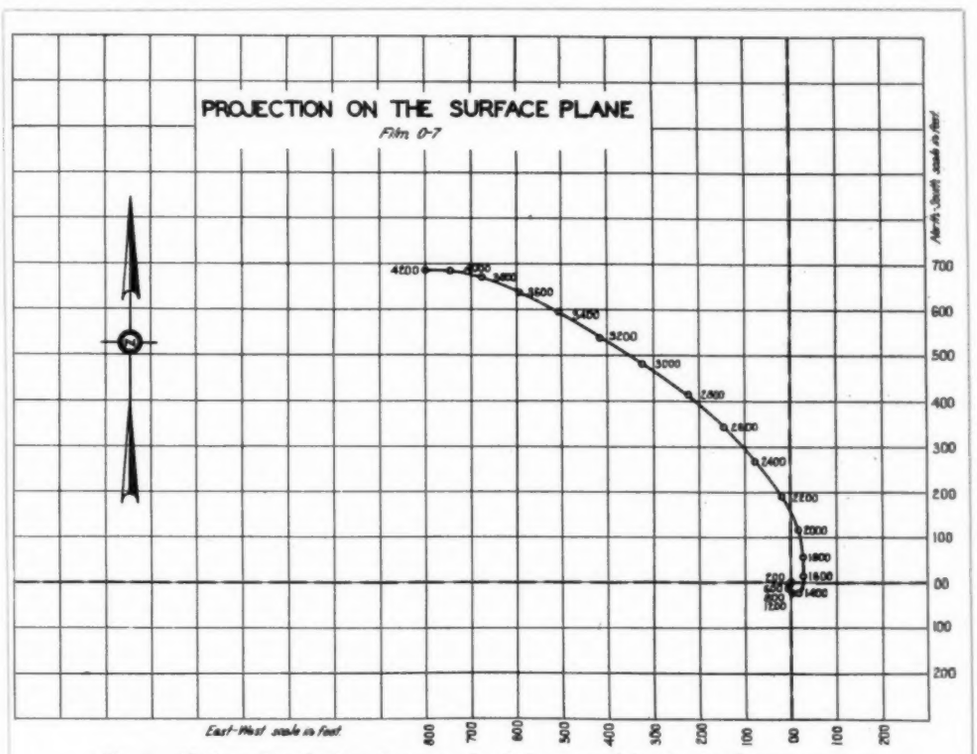


Fig. 1. Horizontal projection of course of a hole surveyed by the Sun-Sperry gyroscope.

At the International Petroleum Exposition, Tulsa, the Sun Oil Company had on display an apparatus developed jointly by them and the Sperry Gyroscope Company for the purpose of accurately and quickly surveying the course of a drilled or drilling well. This apparatus has been tested exhaustively in the laboratory and over a period of several months has made repeated surveys and checked surveys of various holes in Texas and Oklahoma. The results in all cases may be considered as uniformly good.

The apparatus as developed by the Sun Oil Company is simple in principle and quite compact in design. Although the mechanism is of a rather delicate nature, it has been found to be sufficiently rugged in field operation.

The apparatus consists of a gyroscope, a camera and a bubble, together with the batteries which provide the power supply, completely contained in a high pressure steel case. The whole apparatus is lowered into the hole on the end of a wire line and records are taken automatically at short intervals throughout the hole (both going in and coming out) without stopping the apparatus at any point in the hole

The simple gyroscope, as is well known, holds its orientation in space due to fundamental principles of mass of inertia in rotating bodies. A north-seeking gyroscope will maintain its axis parallel to the earth's axis no matter how the case containing such a gyroscope may be moved, rotated or tilted and this directive action is entirely independent of the earth's magnetism or any magnetic materials which may be associated with the gyroscope. Such a gyroscope if displaced from its North-South orientation will return to that orientation. Another type of gyroscope if placed in a position so that its axis is parallel to the earth's axis will retain that position, but if it is displaced from that orientation it will not return to it. The apparatus as used in the surveying of crooked holes utilizes this type of gyroscope since it obviates possibilities of errors in orientation while in the hole, as such errors are immediately apparent upon the return of the apparatus to the surface.

The direction of a pointer controlled by the gyroscope, the position of the bubble in the level, and the time shown by a small watch are all photographed at regular intervals in running into and coming out of the hole. The depth of the instrument is recorded on the derrick floor for any given time periods so that when the film is developed the data include the depth of the instrument at any given time together with the orientation and inclination. From these data the direction and inclination of the well are calculated.

The apparatus as utilized at present has a capacity of approximately one thousand observations. When distributed over the length of the hole this gives records at intervals of approximately ten feet while going into and coming out of a 5,000-foot well. The time required for the actual surveying of such a well is an hour or less.

The errors of the surveys when checked repeatedly by independent runs in the same well have never exceeded one

per cent of the depth of the hole and as the technique and apparatus are improved it would seem safe to say that the errors would never exceed one-half of one per cent of the depth of the well; in other words, an error of location of the bottom, of twenty-five feet in a 5,000-foot well.

At the present state of the industry a further advantage of this instrument lies in the fact that the results of the survey of any well are available to only one man and that one man need not be the man who actually does the survey of the well. The undeveloped record may be taken from the camera and turned over to the representative of the owner of the well immediately upon the completion of the run and he may develop the record and make the computations himself. In this manner but one man knows the course of the hole.

This apparatus for the surveying of crooked holes was developed by the Sun Oil Company for use in its own wells but inasmuch as its advantages are so apparent it seems probable that the apparatus will be made available to the petroleum industry in the near future.

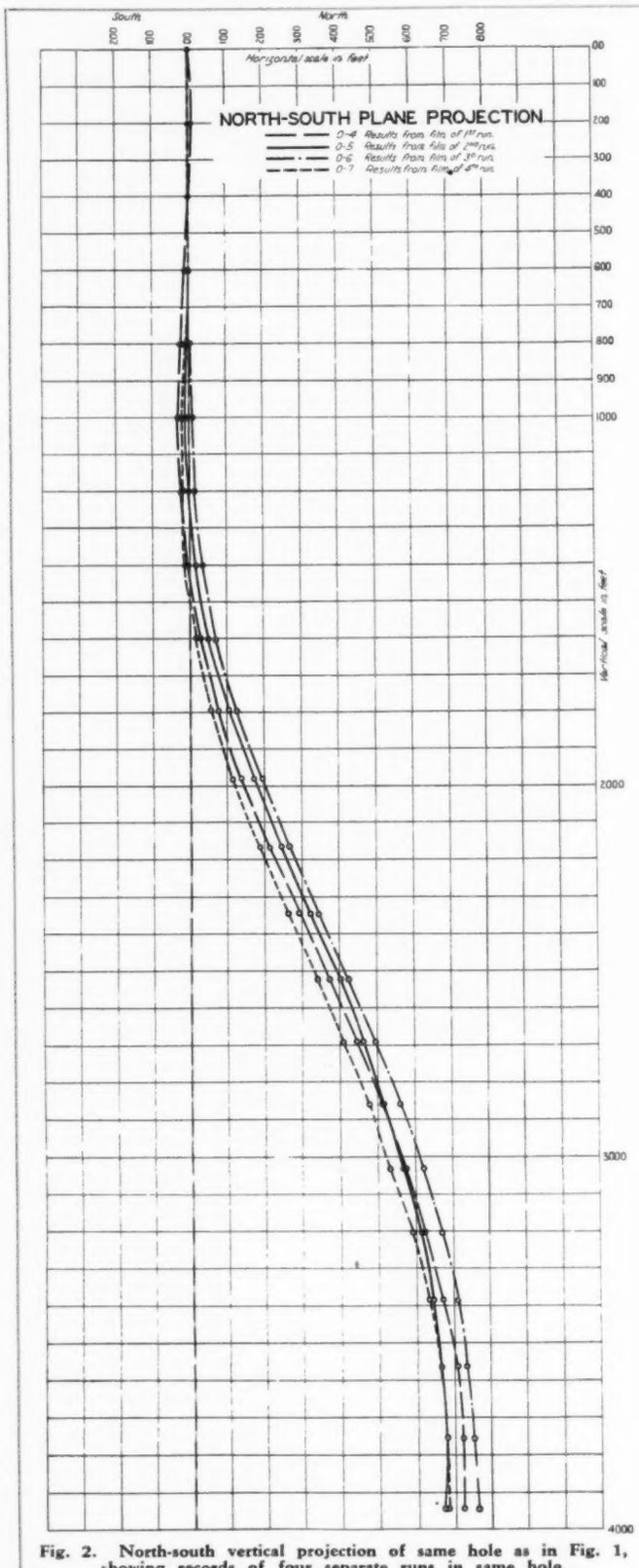


Fig. 2. North-south vertical projection of same hole as in Fig. 1, showing records of four separate runs in same hole.

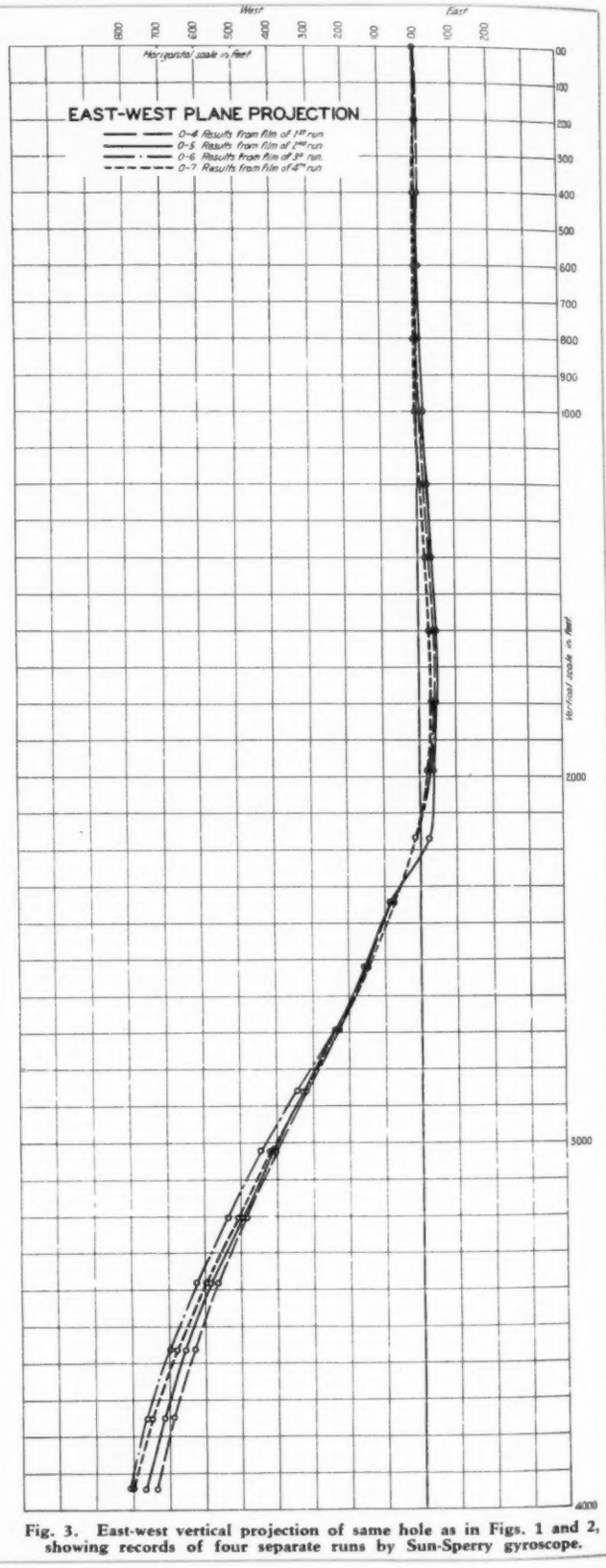
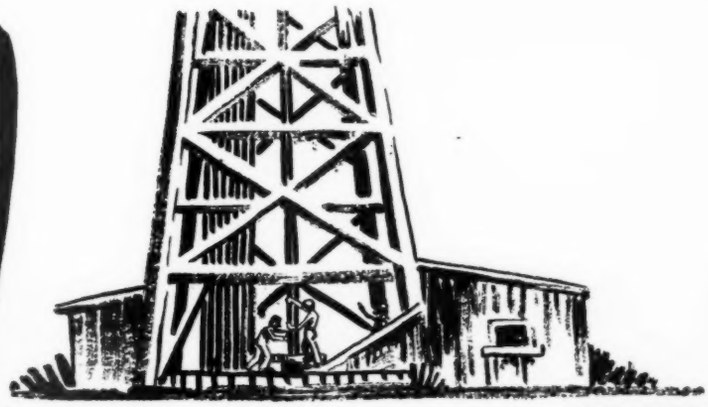
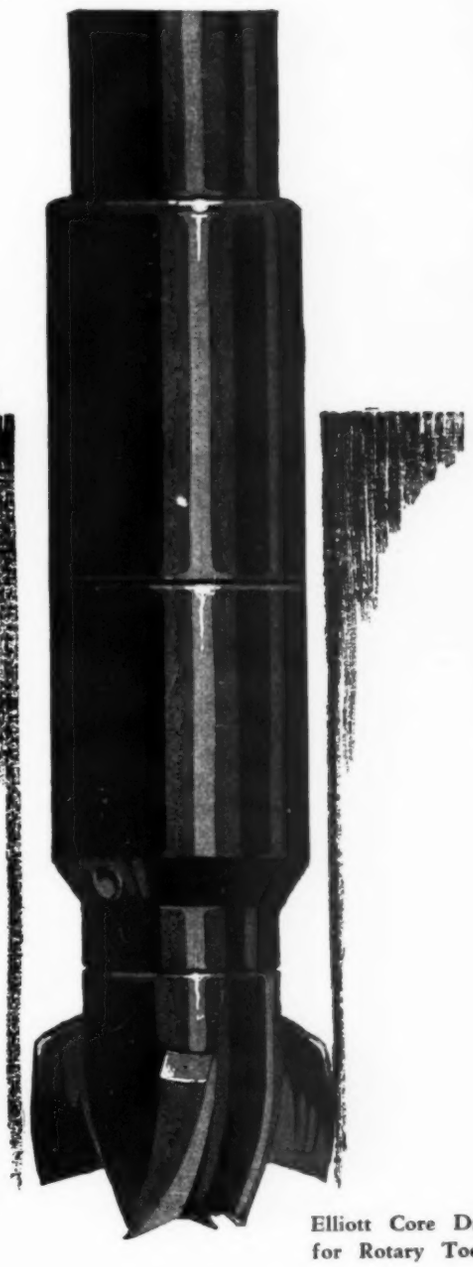


Fig. 3. East-west vertical projection of same hole as in Figs. 1 and 2, showing records of four separate runs by Sun-Sperry gyroscope.





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The Effects of Controlled Pressure on

FLOWING OIL WELLS

By I. B. WILLIAMS

PROPERLY controlled pressure or what is ordinarily known as back pressure, produces the following results on flowing oil wells:

(A) Normal daily production (Increased daily production over open flow methods, except where temporary excessive stimulation is resorted to).
(B) Water shut-off (water which has its origin in the oil sand).
(C) Lowered gas-oil ratio or gas factor.
(D) Greatly increased ultimate production.

Increased Daily Production

When back pressure is applied to a flowing oil well at least two basic physical reactions take place:

(1) The differential flowing pressure from the sand reservoir to the bottom of the well is reduced.

(2) The static pressure at and near the exposed face of the sand is raised.

The immediate effect of (1) is a decrease of the velocity of flow of oil, gas and water toward the well.

The slower or more gradual effect of (2) on the oil and gas is manifested by a redissolving of a portion of the natural gas and lighter hydrocarbon mixtures into the oil, due to the increased static pressure in the immediate vicinity of the well bore.

The reabsorption of natural gas and light fractions into the oil lowers the viscosity of the oil in the sand, or increases the fluidity of the oil. The term fluidity probably is preferable in this instance, because it is the resultant condition or change covering all physical changes such as, lowered viscosity, decreased surface tension and decreased cohesion.

The effect of increasing fluidity of the oil by the absorption of gas and gaseous constituents, takes place at a faster rate than the effect of the lowered differential, up to a certain critical percentage of back pressure.

It is self-evident, then, that if the resistance to the flow of oil is decreased (by increasing its fluidity) to a greater degree than the opposite effect of lowered differential flowing pressure, at least as much or more oil will flow toward the well, when back pressure is applied within critical limits, than if no back pressure were applied. That this statement is true has been established by experimental work on the flow of oil and gas mixtures through actual oil sand cores. Comparative production decline curves, figures 1 and 2, on oil wells carried over a *long period* of time are further and more satisfactory proof of this claim.

Some further favorable effects of controlled pressure on oil wells are worthy of note. Proper regulation of back pressure on an oil well that has previously been produced under open flow methods recharges the sand in the immediate vicinity of the well with a highly-charged, effervescent mixture of gas and oil and volatile constituents, in character very similar to the conditions that exist when a well is first drilled in. This favorable change is well exemplified by a comparison of the shut-in pressure of a well after it has been produced for a time under proper pressure control with the shut-in pressure of the same well while being produced under open flow methods. Two examples of this pressure change are given below:

Example 1. Torsey Baker No. 1 (Magnolia Oil Co.), Weleetka, Okla. Shut-in pressure November 2, 1926, 14 hours—130 pounds while being produced on pump.

Casinghead working pressure while flowing under controlled back pressure, November 17 to December 31, 1926—375-395 pounds.

Shut-in pressure December 1, 1926, to test, 1 hour and 15 minutes—690 pounds.

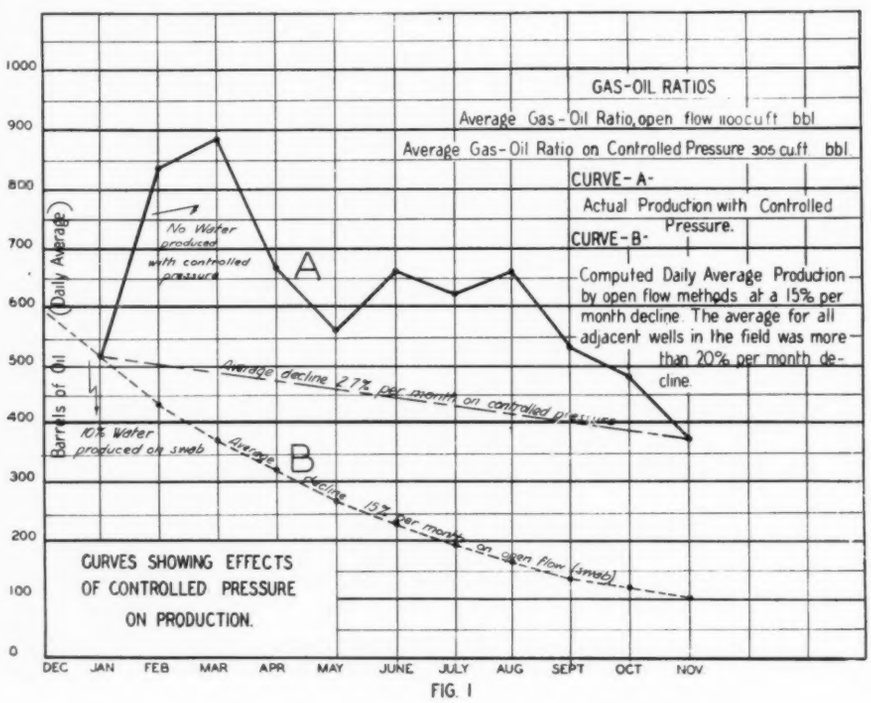
Example 2. Henry No. 2 Well (Barnsdall Oil Co.), Seminole, Okla. Well flowing with spray flow.

Casinghead working pressure April 1, 1928, operating under controlled pressure—220 pounds.

Casinghead working pressure June 25, 1928, operating under controlled pressure—340 pounds.

Casinghead working pressure July 15, 1928—355 pounds.

There was an increase in casinghead working pressure of 155 pounds in a period of three and one-half months on this well under proper pressure control. Both wells had an in-


GAS-OIL RATIOS
Average Gas-Oil Ratio, open flow 1100 cu ft bbl
Average Gas-Oil Ratio on Controlled Pressure 305 cu ft bbl
CURVE-A-
Actual Production with Controlled Pressure.
CURVE-B-
Computed Daily Average Production by open flow methods at a 15% per month decline. The average for all adjacent wells in the field was more than 20% per month decline.
No Water produced with controlled pressure
A
B
Average decline 27% per month on controlled pressure
10% Water produced on swab
Average decline 15% per month on open flow (swab)
Barrels of Oil (Daily Average)
CURVES SHOWING EFFECTS OF CONTROLLED PRESSURE ON PRODUCTION.
1000
900
800
700
600
500
400
300
200
100
0
DEC JAN FEB MAR APR MAY JUNE JULY AUG SEPT OCT NOV
FIG. 1

crease in oil production during the period of increasing pressure.

Water Shut Off

Controlled pressure has an effect on the flow of water into a well.

Water flow through porous media such as an oil sand — or, for that matter, through any kind of openings — theoretically is proportional to the square root of the differential flowing pressure. Stated concretely, if 50 barrels of water per day were produced in an oil well with a differential flowing pressure of 500 pounds per square inch, about 35 barrels per day would be produced if the differential flowing pressure were one-half, or 250 pounds per square inch, other things being equal. There is, however, another very vital condition to take into consideration with the question of water flow through an oil sand. The pore openings in the sand are microscopic in size. The effect of friction in such minute openings is enormous. Even a very small decrease in the differential often will completely prevent the movement of water. For example, a core of ordinary oil sand eight inches in length required a pressure of 250 pounds per square inch to just force water through it. A pressure of 240 pounds per square inch, or 10 pounds less, failed to force the water through. Investigators who have worked with this phase of the subject can readily appreciate the effect of a slight amount of back pressure on the flow of water through an oil sand.

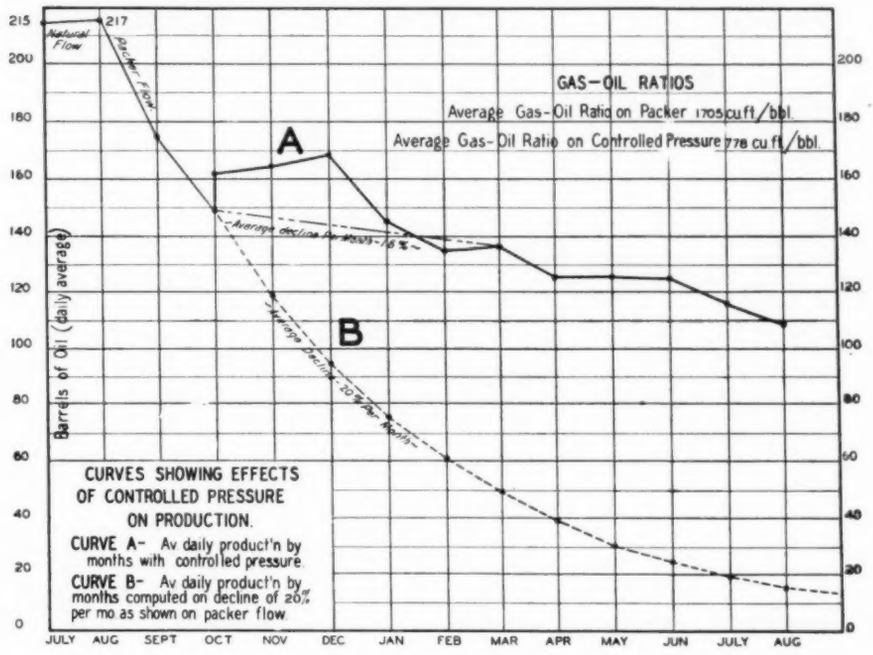

GAS—OIL RATIOS
Average Gas-Oil Ratio on Packer 1705 cu ft/bbl.
Average Gas-Oil Ratio on Controlled Pressure 778 cu ft/bbl.
A
B
Natural Flow
Packer Flow
Average decline for 2 mos.-16 %
Average Decline 20 % Per Month
Barrels of Oil (daily average)
CURVES SHOWING EFFECTS OF CONTROLLED PRESSURE ON PRODUCTION.
CURVE A- Av daily product'n by months with controlled pressure
CURVE B- Av daily product'n by months computed on decline of 20% per mo as shown on packer flow.
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FIG 2

Gas-Oil Ratio

The number of cubic feet of gas required per barrel of oil produced, called the gas-oil ratio or gas factor, is the important factor from the point of view of the ultimate production of oil from a well or from the structure. Wells that have a high gas-oil ratio invariably have a rapid rate of decline, not entirely because the gas pressure is rapidly depleted from the entire structure, but equally as much or more because of a plugging-up process on the sand pores at the exposed face of the sand (the point of greatest pressure drop) and gradually extending back therefrom radially. This plugging process is brought about by:

(a) Rapid escape of lighter hydrocarbons from the oil—when the flow is predominantly a gaseous spray—accompanied by a deposition of heavy viscous residue oil in the sand pores immediately surrounding the well.

(b) Very rapid if not almost sudden depletion of the gas and gas pressure in the immediate area surrounding the well. The extent of this depleted area varies with the gas-oil ratio, the physical structure of the sand, and the character of the oil. With a high gas factor the area is comparatively small. Also with a tight sand or a heavy oil the area will be small.

(c) Water coning and trapping of oil and gas due to the maintenance of a high differential flowing pressure from the formation to the sand face.

When back pressure is applied at the sand face of a well, the velocity of the gas is slowed up to approach the slower velocity of the oil. The oil absorbs gas, becomes more fluid and is therefore able to flow more easily through the sand. There is thus set up a condition which tends toward a decrease in gas volume due to gas velocity decrease, accompanied by a tendency toward increase in oil volume due to fluidity increase, and therefore oil velocity increase.

The critical back pressure is reached when the favorable effect of fluidity change of the oil is offset by the opposite effect of lowered differential flowing pressure. Back pressure applied beyond this critical point will not decrease the gas-oil ratio but will decrease the oil production.

Violent gaseous spray flow will not bring out of the structure or even out of the well bore as much oil per unit time as a slower uniform piston flow. What is referred to here as piston flow is a type of flow wherein the oil and gas flow out of the well in alternately arranged pistons of oil and gas. A slug or piston predominantly oil, followed by a piston predominantly gas at intervals of a few seconds, is a characteristic piston type of flow and is the most efficient flow in the flowing tube to obtain a minimum gas factor. Piston flow reduces the gas-oil ratio in an oil well for the same reason that a "tight piston" in an automobile engine is more efficient than a loose one.

Another extremely important factor necessary to reduce the gas-oil ratio is the securing of a thoroughly intimate mixture of the oil and gas just prior to commencement of flow. Except when an oil well is in its very earliest stage of flowing life—immediately after the reservoir is tapped—is the mixture correct for efficient utilization of the gas. This condition does not maintain for very long of its own accord, but tends to become more and more unbalanced until the well ceases to flow at all, even though there is yet sufficient gas and gas pressure available. It is therefore necessary to mix continuously, by some mechanical means, the oil and gas prior to flowing in the well, in order to utilize efficiently the gas.

A summing up of the factors necessary to secure efficient use of the gas in flowing oil wells is as follows:

1. Back pressure applied within the critical limits.
2. Facilities for securing and maintaining a piston type of flow.
3. Securing a continuous mechanical mixture of the oil and gas prior to flow.

There must be a complete balance of equilibrium between all phases to maintain successfully a minimum gas factor.

EDITOR'S NOTE: Mr. Williams' concluding paper will appear in an early issue.

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Flow Resistance of Gas-oil Mixtures

Through Vertical Pipes[1]

By L. C. UREN,* P. P. GREGORY,† R. A. HANCOCK† and G. V. FESKOV,† Berkeley, Calif.

THE resistance to flow of mixtures of gas and oil in passing up through the flow tubing of oil wells operated by gas-lift or by natural flow is a factor in oil-recovery technic that has received but little attention. Yet accurate design of a tubing installation for a particular set of conditions, where operation is by either of these methods, is impossible without quantitative data on the pressure loss suffered by the oil-gas mixture in its passage through the well tubing to the surface. Because of lack of such information, petroleum production technologists have been compelled to approach this problem by "cut-and-try" methods, which, doubtless in many cases, has resulted in the installation and use of tubing too large or too small for most efficient utilization of the expansive force of the gas used in lifting the oil. Impressed with the necessity for information of this character, the authors have conducted a series of tests with large-scale apparatus in the petroleum engineering laboratories of the University of California, designed to be productive of data that would afford a means of attacking the problem of flow-tubing design on a more scientific basis.

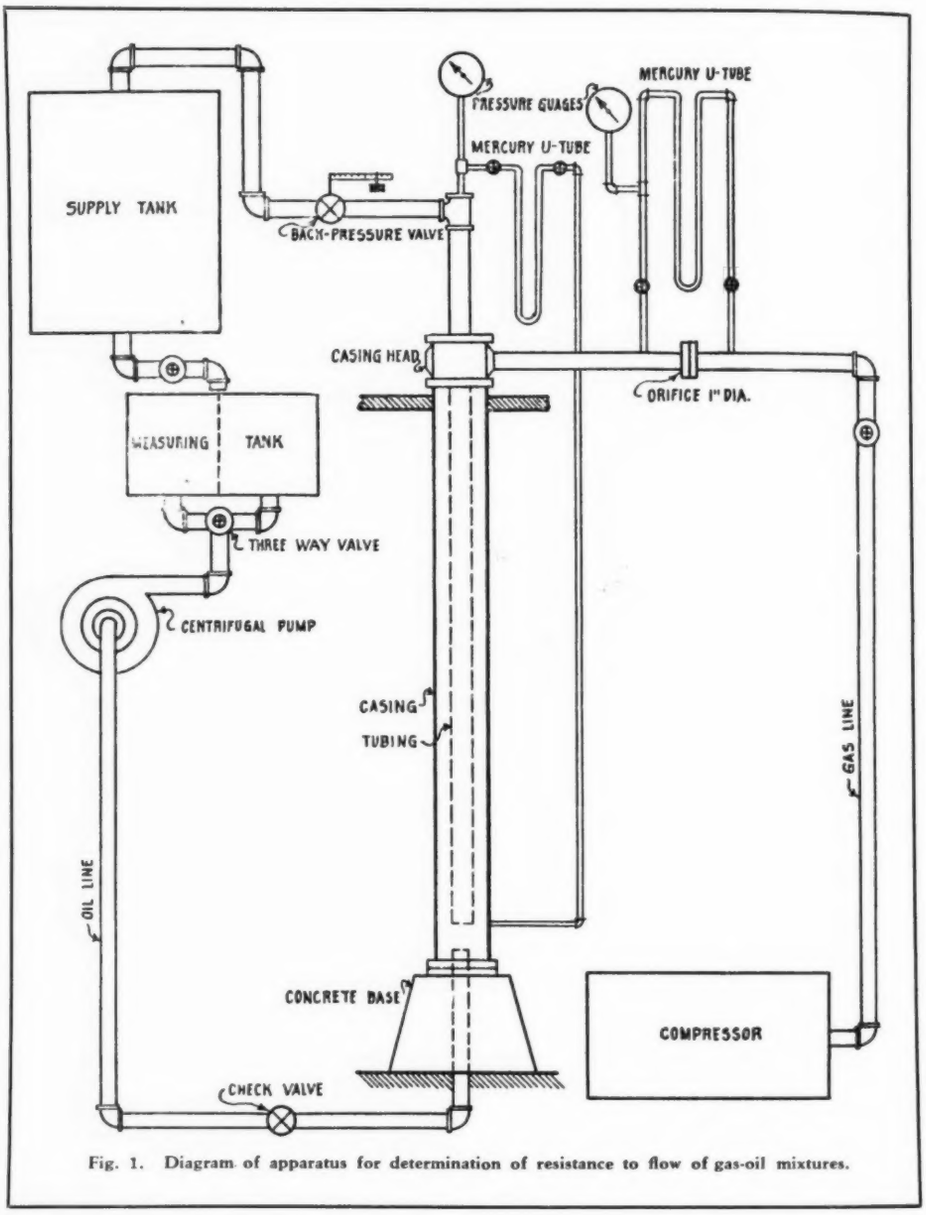

Fig. 1. Diagram of apparatus for determination of resistance to flow of gas-oil mixtures.

Mechanics of Expulsion of Gas-Oil Mixtures in Naturally Flowing and Gas-lift Wells

When oil is lifted from a well by the expansive force of compressed natural gas or air, the fluids enter the lower end of the eduction tube under elevated pressure, with the gas partly in solution, but largely distributed in the form of occluded bubbles within the oil mass. As discharged from deep wells, after reaching the surface, there will normally be at least 60 times as much gas, by volume, as of oil; and in many cases the ratio of gas volume to that of the oil will have a value as great as 1,000 or more. On entering the lower end of the eduction tube, however, a relatively smaller volume of gas will be found in the oil-gas mixture, on account of compression of the gas in accordance with the elevated pressure necessary. If the pressure at the point of admission to the eduction tube were, say, 300 lb. per sq. in., the relative volume of the gas to that of the oil at that point would range from a minimum of approximately 3 to 1 to 50 to 1, or higher. In all cases we are dealing with gas-oil mixtures in which the volume of gas is materially greater than that of the oil.

The mixture enters the lower end of the eduction tube with the ratio of gas volume to oil volume at a minimum value for the conditions existing; but as the fluid mixture rises, the pressure diminishes and the gas expands. The ratio of gas volume to oil volume is therefore continually increasing as the fluids rise, reaching a maximum at the surface, where the pressure is lowest. Such gas as exists

[1] Presented before the Fall Meeting of the A. I. M. E. at both Tulsa, Okla., and Los Angeles, Cal.

* Professor of Petroleum Engineering, University of California.

† Recently graduated students in Petroleum Engineering, University of California.

in solution at the higher pressures is released on reduction of pressure, assuming the gaseous phase and further adding to the rapidly growing volume of fluid passing upward through the eduction tube.

Since the volume of fluids passing up through the eduction tube rapidly increases as the pressure is released, it follows that if the tube is of the same diameter throughout, the velocity of flow must continually increase, being a minimum at the bottom and reaching a maximum value at the top. Computations based on operating conditions in typical naturally flowing and gas-lift wells, in which flow occurs

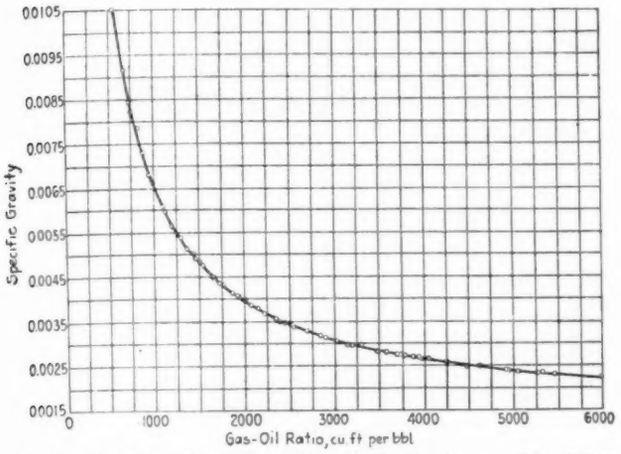

Fig. 2. Variation of specific gravity of air-oil mixtures with different gas-oil ratios.

through tubing of from 2 to 4 in. dia., show flow velocities ranging from a few to many hundred feet per second.

The character of flow through the eduction tube is doubtless turbulent, it being inconceivable that viscous flow could exist within a non-homogeneous fluid mass moving through a tube of restricted cross-section at such high velocities.

As gas expands, it suffers a definite loss in temperature. Expansion of gas within the eduction tube is not adiabatic, however, as the oil—within which the gas is occluded—the walls of the tubing and the surrounding rock masses offer a reservoir of heat ready largely to make up loss in temperature, which would otherwise result through gas expansion. Expansion of the gas is probably nearer isothermal than adiabatic.

Energy released by expansion of gas as it rises through the eduction tube is applied in two ways: (1) in lifting the fluid mass, and (2) in overcoming frictional resistance to flow. The flow resistance is made up of two components: (a) frictional resistance against the walls of the tube, and (b) internal friction within the fluid mass in adjusting itself to the rapidly increasing gas volume, and the fluid friction of gas-oil surfaces in turbulent flow.

Variables Influencing Pressure Loss in Flow of Fluids Through Pipes

In approaching the problem of evaluating and formulating the variables influencing pressure loss, the authors have assumed that the Fanning formula would comprise all of the variables involved. This formula has been demonstrated to have a wide range of application, including computations of pressure loss of oils and gases through pipes.[1] The several variables involved are related as follows:

$$P = \frac{0.323\,fLSV^2}{D}, \text{ in which}$$

P is the pressure loss (in pounds per square inch) sustained by a fluid of specific gravity S, in moving through a pipe of internal diameter D (in inches) and length L (in feet), at velocity V (in feet per second). The friction factor f is a function of the product of the pipe diameter D, the flow velocity V, and the specific gravity S, divided by the viscosity Z, which may be conveniently expressed in centipoises; that is, f varies as the value of the expression $\frac{DVS}{Z}$. It appears that if the value of f is arbitrarily made equal to $0.00207 \times \frac{Z}{DVS}$, the Fanning formula becomes equivalent to the Poiseuille formula, in which

$$P = \frac{0.000668ZLV}{D^2}$$

and holds true over the entire range of turbulent and viscous flow.

These expressions have been used in computing the values of f, the friction factor in the Fanning equation, and Z, the absolute viscosity for various gas-oil mixtures, from observed data assembled in the course of the experimental tests described below. Values for P, the pressure loss, were experimentally determined for many different measured flow velocities, V, in a pipe of known diameter D and length L. Values of S, the specific gravity, for different gas-oil mixtures, were computed from the known specific gravities of the oil and gas used and the percentages of each in the oil-gas mixtures. With all variables in the Fanning formula, except f, experimentally measured or computed, it has been possible to solve directly for values of f. Knowing the values of f, D, V and S, it has also been possible to compute corresponding values for the absolute viscosities of the gas-oil mixtures used.

Apparatus Used in Flow Tests

The apparatus used in making the pressure-loss tests is illustrated diagrammatically in Fig. 1. The "well" consists of a vertical column of 5½-in. casing, 42 ft. high, the lower end being supported on a concrete pedestal and closed by a blind flange except for a short 2-in. pipe, which penetrates

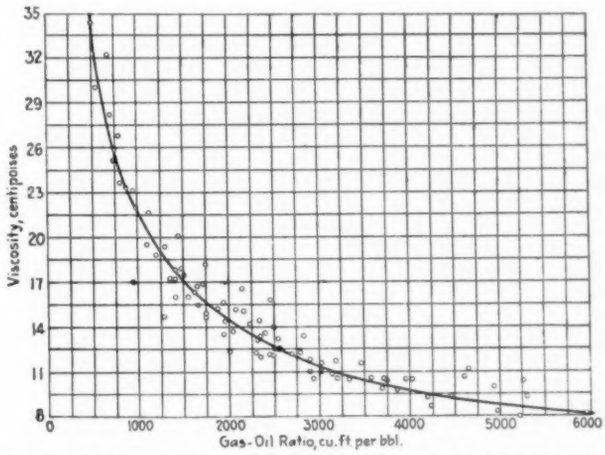

Fig. 3. Variation of viscosity of air-oil mixtures for different gas-oil ratios.

the flange and pedestal from below. A column of 2-in. oil-well tubing 41.4 ft. long is suspended within the casing from a gastight casinghead, the lower open end of the tubing being about 2 ft. off bottom. This serves as the eduction tube.

A 25-bbl. tank provides storage for surplus oil above the casinghead. From this tank, oil flows—with suitable valve

[1] R. E. Wilson, W. H. McAdams and M. Seltzer: The flow of Fluids through Commercial Pipe Lines. *Jnl. of Ind. & Eng. Chem.* (1922) 14, 105.

control—into a gaging tank having two compartments, each of 1½-bbl. capacity. A swing connection permits of alternately diverting the oil flow to one or the other of the two compartments, one filling as the other is emptied. From either of the two compartments of the gaging tank, oil is taken through a three-way valve into the suction line of a small centrifugal pump which discharges it under pressure into the lower end of the vertical column of 5½-in. casing.

A supply of compressed air is available, which is led into one of the side outlets of the casinghead, thence down through the annular space between the tubing and casing to the lower end of the tubing, where it meets the ascending stream of oil, both fluids simultaneously entering the open, lower end of the eduction tube, where they become intimately mixed. The volume and pressure of the air used is recorded with the aid of an orifice meter equipped with appropriate differential and static pressure gages. The oil-gas mixture, after rising through the eduction tube, is discharged through an adjustable back-pressure valve into the 25-bbl. storage tank, where the fluids come to rest for a sufficient time to allow all the air to escape from the oil.

Means are thus provided for accurately measuring the volume of oil and the volume and pressure of air entering and passing through the eduction tube at any time. Pressure conditions at the lower end of the eduction tube, and the ratio of gas to oil in the mixture, may be altered within a considerable range by adjusting the speed of the centrifugal pump and the pressure and volume of air passing the orifice meter. The pressure under which the gas-oil mixture is discharged at the upper end of the eduction tube may also be varied within limits by adjusting the weight-and-lever control on the back-pressure valve.

In order to measure the pressure loss between the lower and upper ends of the eduction tube, a ¼-in. pipe is tapped into the 5½-in. casing, opposite the lower end of the tubing, while a second connection is made directly into the upper end of the tubing. These tubes communicate with opposite legs of a mercury manometer and the differential pressure between the two ends of the eduction tube is thus indicated. A spring pressure gage also records the static pressure at the upper end of the column.

Manipulation of Equipment in Conduct of Tests

In starting a "run," both sections of the measuring tank are filled with oil from the supply tank, then air is turned into the casinghead and the back-pressure valve is adjusted to give the desired discharge pressure. When the flow of air becomes uniform, one section of the measuring tank is connected with the pump suction and the pump is started, allowing the oil to flow into the bottom of the "well," the speed of the pump being adjusted to provide the desired rate of oil flow.

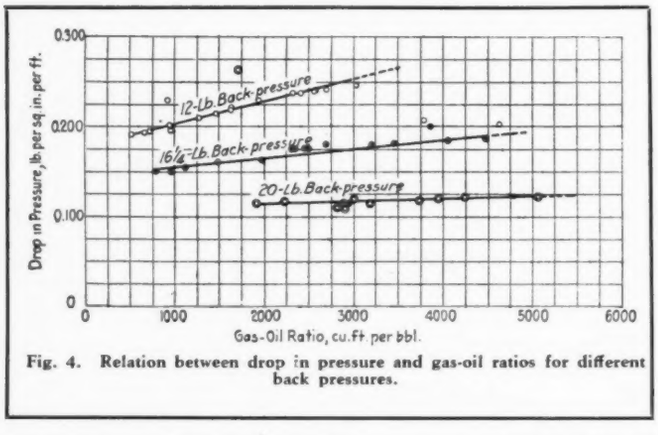

Fig. 4. Relation between drop in pressure and gas-oil ratios for different back pressures.

The lift is now operating, a mixture of air and oil rising through the eduction tube and discharging into the storage tank. As soon as flow conditions have reached equilibrium, the oil in the full section of the measuring tank is gaged. Because of the short lift, only a few minutes are necessary to establish a condition of uniform flow. By means of the three-way valve, the full section of the tank is now "cut in" and flow continued until this section is nearly emptied, when it is again gaged. The two gages provide an exact measure of the quantity of oil used in the run. Readings are taken of the pressure gages and manometer at intervals during the run. The differential pressure between the top and bottom of the tubing gives the pressure drop for the particular conditions prevailing, and the quantity of air used is computed from the static and differential pressures on the orifice-meter gages.

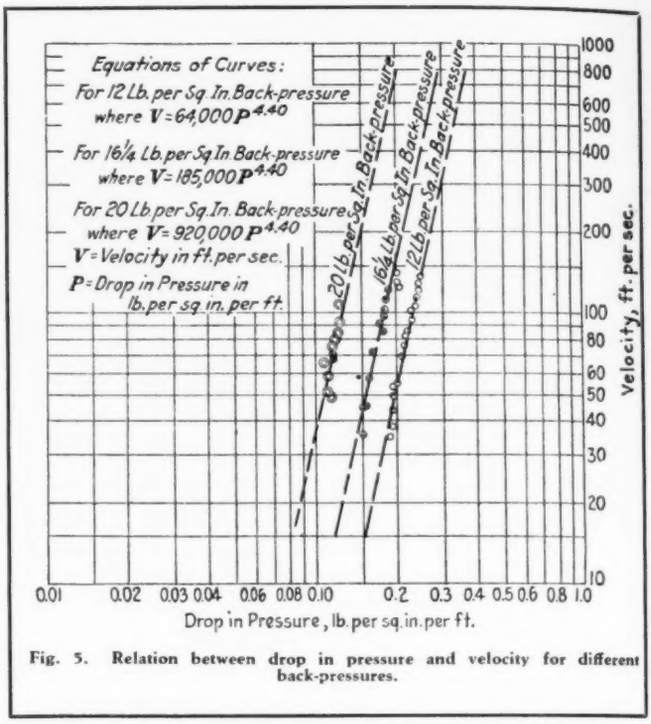

Fig. 5. Relation between drop in pressure and velocity for different back-pressures.

Properties of Oil Used

The oil used in these tests was a residuum fuel oil having an A.P.I. gravity of 18.3°, and a Saybolt Furol viscosity of 270 sec. at the test temperature, which remained practically constant throughout the entire series of tests.

Results of Tests

One hundred separate runs were made, under a wide variety of conditions, providing air-oil ratios ranging from 520 to 7050 and flow velocities in the eduction tube ranging from 35 to 108 ft. per sec. The pressure loss was found to range from 0.109 to 0.356 lb. per sq. in. per linear foot of flow. The Fanning equation friction factor and the viscosity of the air-oil mixture were computed for each run. The reader will not be burdened with tabulated data and details of the computations. Instead, the authors have adopted the plan of using graphs for displaying the results of the tests and the relationships found to exist between the several variables controlling pressure loss. These graphs are presented in Figs. 2 to 7 herewith.

Fig. 2 displays the computed variation in specific gravity for air-oil mixtures ranging from 500 to 6000 cu. ft. of air per barrel of oil. The density of air is here taken as 0.0013 and that of the oil as 0.94. The graph shows the value of S in the Fanning formula for the particular oil and gas used throughout the tests.

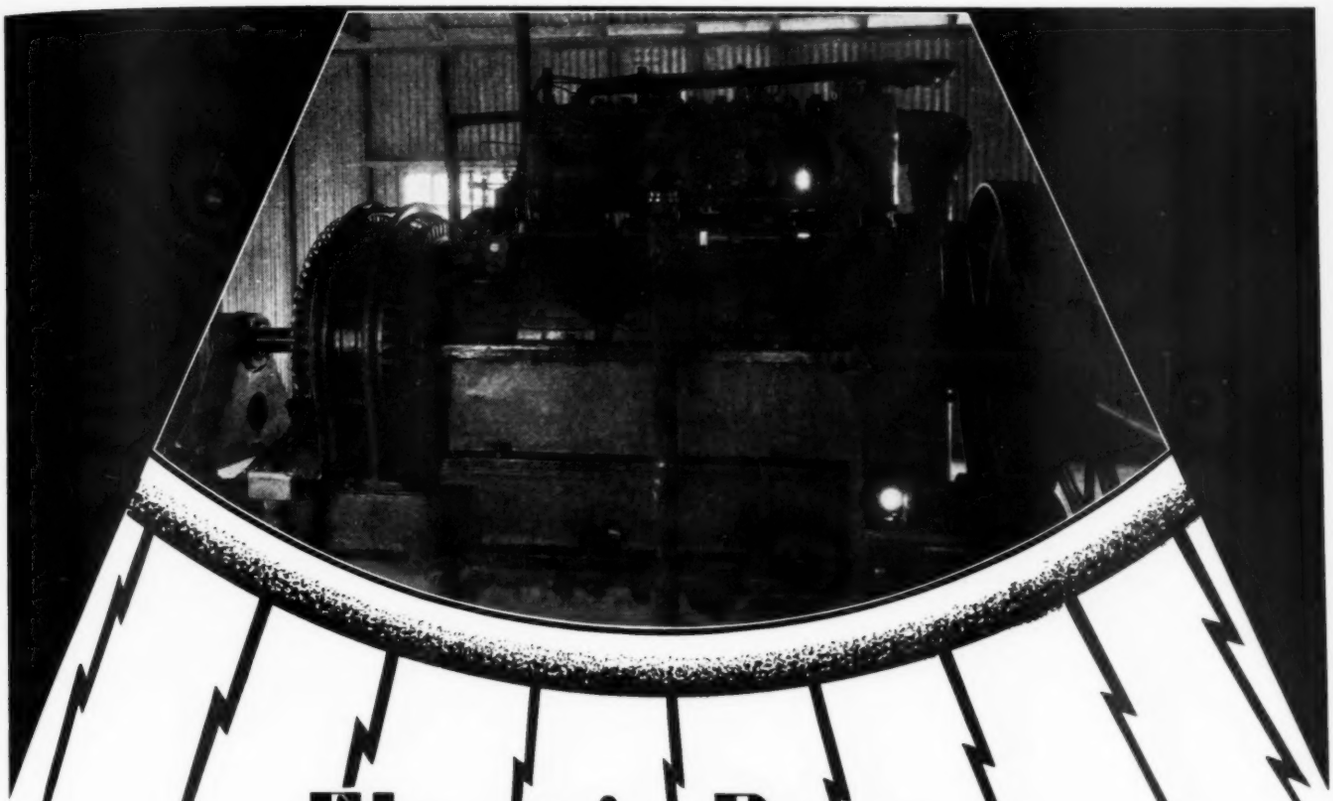

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Fig. 3 shows how the computed values of absolute viscosity of air-oil mixtures diminish as the air-oil ratio increases. Important reductions in viscosity are secured by increasing the percentage of air in the mixture. This tends to reduce the frictional loss in moving the fluid through the eduction tube but, as will be shown in a later graph, the advantage so gained is more than offset by the greater flow velocity made necessary by increased volume of fluid to be handled.

The three graphs of Fig. 4 demonstrate that a straight-line relationship exists between the loss in pressure and the air-oil ratio, the pressure loss per linear foot of tubing traversed increasing directly as the volume of air in the fluid mixture increases. It seems probable that this relationship does not exist over the entire range of possible mixtures, the data indicating that at a ratio of between 300

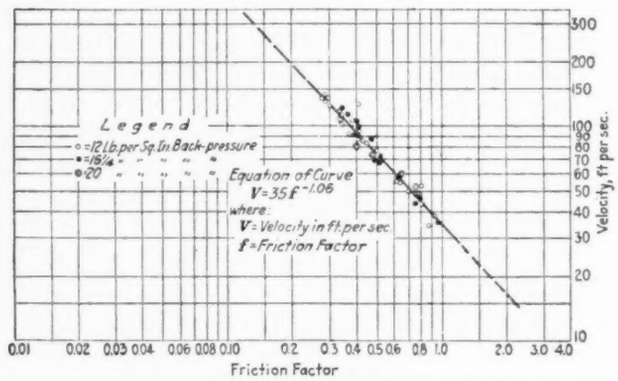

Fig. 6. Relation between friction factor and velocity.

and 500 there is a critical inflection point at which a reversal in the slope of the graphs will occur, the flow resistance increasing below this critical point as the air-oil ratio diminishes. The reason for this change in the characteristics of the graphs is found in the fact that the loss in pressure is controlled primarily by three variables—namely, flow velocity, density and viscosity of the air-oil mixture. At low gas-oil ratios, governing factors are the reductions in specific gravity and viscosity of the mixture, which act in a direction opposite to that of increased flow velocity. It is estimated, for the conditions presented in these tests, that at a value of between 300 and 500 for the air-oil ratio the three factors will determine a point of minimum flow resistance. It is regrettable that the tests could not be conducted at ratios low enough to determine this point experimentally, but it is interesting to note that it lies considerably below the range of gas-oil ratios normally attained in field practice.

Fig. 4 also brings out the interesting fact that the pressure loss per unit of linear travel through the eduction tube is less at high pressures than at low pressures for a given gas-oil ratio. This, of course, is caused by the smaller volume of the gas at elevated pressure, with consequently lower velocity of flow for the fluid mixture.

The effect of flow velocity of gas-oil mixtures on pressure loss is also well demonstrated by Fig. 5, in which the experimentally measured pressure loss of air-oil mixtures, for a wide range of computed flow velocities, is shown for three different conditions of back-pressure. These graphs are of logarithmic type; hence, when plotted on logarithmic coordinates, they become straight lines. It has been possible, therefore, to extrapolate the graphs in both directions beyond the range of the experimental values. These graphs again indicate increased pressure loss with increased flow velocity, and lower unit pressure losses at the same flow velocity for higher fluid pressures. This can only result through diminished viscosity and density, which is attained by higher percentages of gas in the fluid (computed as free gas) at the higher pressures.

The relationship existing between flow velocity and the friction factor f, of the Fanning equation, is indicated in the graph of Fig. 6, which is also of logarithmic type. It will be observed that values for the tests conducted at three different back-pressures fall approximately on a straight line. In other words, this relationship is independent of the pressure. These values for the friction factor are, of course, appropriate only for the conditions applying in the tests from which the data are derived.

The graph reproduced in Fig. 7, however, should be of general application. Here values for the expression $\frac{DVS}{Z}$ are plotted against corresponding values of the friction factor f in the Fanning equation. The computed values of f again indicate a logarithmic relationship. From the graph of Fig. 7, it should be possible to find an appropriate value for the friction factor for any assumed values of the controlling factors, D, V, S and Z, and directly apply the Fanning equation to determine pressure loss. This relationship should hold true for pipe diameters and oil properties differing from those used in the experimental tests, but one must necessarily know the viscosity and density of the gas-oil mixture used in each case. The density of the mixture could be readily computed if those of the oil and the gas and the ratio of both in the mixture were known (as in Fig. 2). The viscosity of an oil-gas mixture could probably only be arrived at by experimental tests, leading to results comparable with those reproduced in Fig. 3; that is, an oil differing in viscosity from that used in the tests, results of which are herein reported, would necessarily produce a different graph for the relation between gas-oil ratio

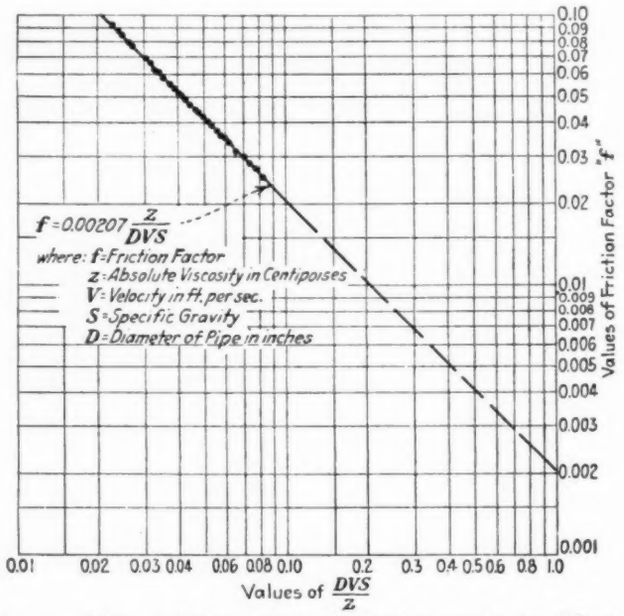

Fig. 7. Values of friction factor in the Fanning equation for different values of fluid viscosity and density, diameter of pipe and flow velocity.

and viscosity, though perhaps one comparable in general characteristics with that reproduced in Fig. 3.

Discussion

LOWER gas-oil ratios than actual are probably obtained when pressure is held on the trap because of the amount of gas lost in solution that goes from the trap with the oil.

Vapor Phase Cracking

By C. R. WAGNER,
Assistant Chief Chemist, The Pure Oil Co.

IN a previous paper[1] some phases of the commercial development of vapor phase cracking were discussed. Interest in this subject is increasing rapidly in the industry because of the character of the products produced. The motor fuel fractions offer a fair substitute for motor benzol for blending with ordinary gasoline in the making of premium antiknock fuels. For example a refiner operating on an average crude containing 30 per cent gasoline can market his entire product as a premium fuel, if he charges his topped crude to a vapor phase cracking plant. For each 1,000 barrels of crude handled he has added to his plant revenues at least $504.00, half of which is collected on what would otherwise be ordinary motor gasoline.

The gases from a vapor phase cracking unit offer unusual opportunities to the refiner. Already these gases are being used in large quantities for the manufacture of glycol, acetone, alcohols and for gas enrichment. The dry gas has a fuel value of about 1,700 B.t.u. per cubic foot which makes it a particularly valuable product for enrichment purposes. Due to its high olefine content it acts also as a carrier for naphthalene and thus assists in one of the most serious problems confronting the gas industry.

With little additional cost it would be possible to separate fairly pure ethylene, propylene or butylene from the gas. The commercial possibilities in marketing these products are enormous. It seems probable, however, that the most profitable utilization of this gas lies in its conversion into motor fuel. It has been discovered that over half of the dry gas produced can be converted into motor fuel distillate of even higher antiknock properties than the original product of the vapor phase cracking operation. This distillate is very rich in compounds boiling between 150° and 300° F., lends itself readily to treatment and yields a stable motor fuel. It appears to have particularly valuable possibilities in the field of aviation fuels.

Among the first to offer to the public a vapor phase cracking process which would compete with liquid phase cracking methods was the Gyro Process Company. By reference to the accompanying flow sheet the method of operation and the salient features of the process become evident. The highest pressure used in the system is about 100 pounds gauge and this is on the cold oil spray to the arrester. The evaporator carries the highest vapor pressure of the system and this ordinarily runs between 10 and 20 pounds gauge. The converter, to which are localized all temperatures above 750° F. used throughout the entire apparatus, can contain not more than 10 gallons of oil as vapor at any one instant.

Owing to the method used in delivering vapors to the converter it is possible to handle any grade of oil as charging stock. Fractions boiling within the range of the motor fuel desired are eliminated at once and by control of the oil line temperature and rate of steam flow into the evaporator as much or as little of the charging stock as desired may be eliminated as fuel oil. Charging stock from the tank (A) is delivered by means of the pump (B) to the arrester (C) spray nozzles where the vapors leaving the converter (I) are reduced in temperature from about 1100° F. to 600° F. The liquid from the arrester which consists of residuums from the charging stock plus any condensed material from the converter passes by gravity to the hot oil revervoir (D). The vapors from the arrester, which consist of vaporized portions of the charging stock plus uncondensed products of the converter, pass to the fractionating tower (J). This fractionating tower is so designed that the distillate which is condensed from the vapors leaving the top of it will have a boiling range commensurate with the motor fuel desired. This boiling range is controlled by means of the refluxer (O) which may be arranged, as shown on the flow sheet, for the production of low pressure steam. The quantity of steam produced in this manner is more than enough to operate all of the pumps used in the process and to supply all of the required process steam. The gas from the gas separator (L) is led to a compressor for the recovery of its liquefiable motor fuel content by any suitable method.

The hot oil reservoir (D) acts as a collector for all of the oil which enters the system which has not yet been converted into motor fuel or fixed gas. The hot oil pump (E) is controlled as to speed so that it will maintain a constant liquid level in the hot oil reservoir (D). The quantity of this hot oil delivered to the economizer (F) is regulated by an automatic rate of flow controller. This rate of flow is so maintained that the converter is constantly supplied with the correct quantity of vapor. The balance of this hot oil is returned to the charging stock tank (A) through either heat exchangers or coolers.

The portion of the hot oil which passes through the economizer leaves the economizer (F) at a temperature of about 700 degrees Fahrenheit and enters the evaporator (G). Here the fuel oil drops out as residuum and is removed from the system through the cooling coil (Q) to the fuel oil tank (R). Superheated steam is introduced into the system through perforated coils in the bottom of this evaporator in quantity not to exceed 3 per cent by weight of the vapors produced. The vapors and steam leaving the top of the evaporator pass through separator (H) which removes particles of entrained liquid. From the separator the vapors pass through a series of preheater or drying tubes in the bottom part of the converter (I) to the inlet of the converter. In these drying tubes the vapors are given about 30° to 50° F. superheat which suffices to remove the white fog that always accompanies any stream of saturated gas oil vapor. These fog particles are in reality tiny drops of liquid oil and unless removed cause some difficulty in the operation of the converter. In passing through the converter the temperature of the vapors is increased to approximately 1100° F. and the conversion to lighter hydrocarbons occurs at this point. In this converter the vapors are distributed by means of the inlet header and passed through a number of tubes in parallel, the tubes containing catalytic cores. From the outlet of the converter (I) the vapors pass into the arrester (C) which was described above.

In developing this process it was necessary to carry on considerable fundamental research work and for this purpose a small unit was developed which would handle about

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* Presented before Fall Meeting of the Manufacturers' Committee, Western Pet. Ref. Ass'n., Tulsa, Okla.
1 *Oil and Gas Journal*, April 25, 1929.

ten barrels of charging stock per day. This unit consists of a cross-section of the commercial installations and therefore gives results which can be interpreted in terms of large scale operation. Quite a variety of charging stocks have been run in an endeavor to learn something of the behavior of these oils under the conditions found in vapor phase cracking. Although these runs were of short duration (24 to 48 hours) it was discovered early in the work that they were readily duplicated and that runs of longer duration added little of value to the results obtained in the short runs.

Below are given results of several runs on various grades of charging stock. Comparison may also be made between different through-puts and lengths of converter tube in the case of Cabin Creek gas oil.

Charging Stock	Cabin Creek Gas Oil	Cabin Creek Gas Oil	Recycle from Cross Stills	Seminole Gas Oil	Winkler Gas Oil	Topped Sweet Lake Crude	Liquid Phase Recycle from Winkler Gas Oil	Mexican Gas Oil	Ranger Gas Oil	Heavy Venezuela Crude Oil	Topped Seminole Crude
Length conv. tube	40 ft.	60 ft.	40 ft.	40 ft.	40 ft.	40 ft.	40 ft.	40 ft.	40 ft.	40 ft.	60 ft.
Throughput gals./hr	61.4	93.5	58.5	60.5	59.2	63.6	59.4	61.2	60.7	79.8	102.4
Temp. exit converter, °F	1100	1068	1112	1099	1108	1100	1128	1114	1112	1075	1067
Gallons charged	476	585	362	254	392	302	457	735	1225	582	629
Per cent distillate	64.0	63.8	53.9	57.5	56.2	49.2	59.5	56.7	54.0	42.8	47.1
Per cent fuel	6.3	6.0	21.0	17.7	18.3	27.8	18.4	11.0	14.0	42.1	33.9
Cu. ft. Dry Gas	13050	13900	7760	5710	10360	7280	9250	20300	29120	6700	10900
Per cent Dry Gas	34.2	29.7	26.8	27.9	29.1	30.1	25.4	34.7	29.7	14.4	21.7
Cu. ft. gas/gal. dist	42.8	37.2	39.8	39.1	41.5	49.0	34.0	48.8	44.0	35.1	36.6
Recirculation ratio	3.09	3.82	3.88	5.71	3.64	5.19	3.12	4.11	3.57	3.30	4.59
Grav. of dist	54.8	54.9	48.1	50.1	46.5	49.9	45.9	57.5	53.6	52.6	51.3
Initial	97	100	104	102	100	99	95	82	94	101	112
10%	168	152	174	173	174	149	164	135	140	162	168
20%	201	191	216	206	219	188	220	164	172	194	204
50%	288	294	318	303	308	290	336	250	276	284	300
90%	389	410	407	395	400	416	397	363	397	382	398
End Pt.	424	435	441	422	431	438	417	593	426	414	426
Iodine No.	206.2	209.8	190.7	205.8	218.2	217.5	168.6	251.4	230.7	162	170
Ref. Index ($N^{20}D$)	1.4328	1.4327	1.4480	1.4438	1.4448	1.441	1.4521	1.4289	1.4362	1.4346	1.4405
Grav. of fuel	13.6	11.1	10.2	9.4	7.1	12.1	7.5	13.6	7.4	3.0	11.9
Sp. Gr. of gas	1.089		1.012	1.020	1.080	0.985		0.985	0.996	1.00	
Additional dist. available by treating gas	16.5	14.3	12.8	13.5	15.8	14.5	12.1	16.6	14.3	6.9	10.4
Total dist. available	80.5	78.1	68.7	71.0	72.0	63.7	71.6	73.5	68.3	49.7	57.5

From the data given in this table it appears that the process is applicable to a wide variety of charging stocks. Inspection of the distillates produced from these various charging stocks shows a remarkable similarity, if they are all rerun to the same boiling point specification. Analyses made of the gases produced also indicate that the character of the charging stock has little to do with their composition. It stands to reason from a study of the cracking reaction that a light charging stock should yield a higher percentage of distillate than a heavy one, since decomposition of the molecules needs to be less profound. In many cases, however, the yield of distillate will be determined by the quality of fuel oil which must be produced.

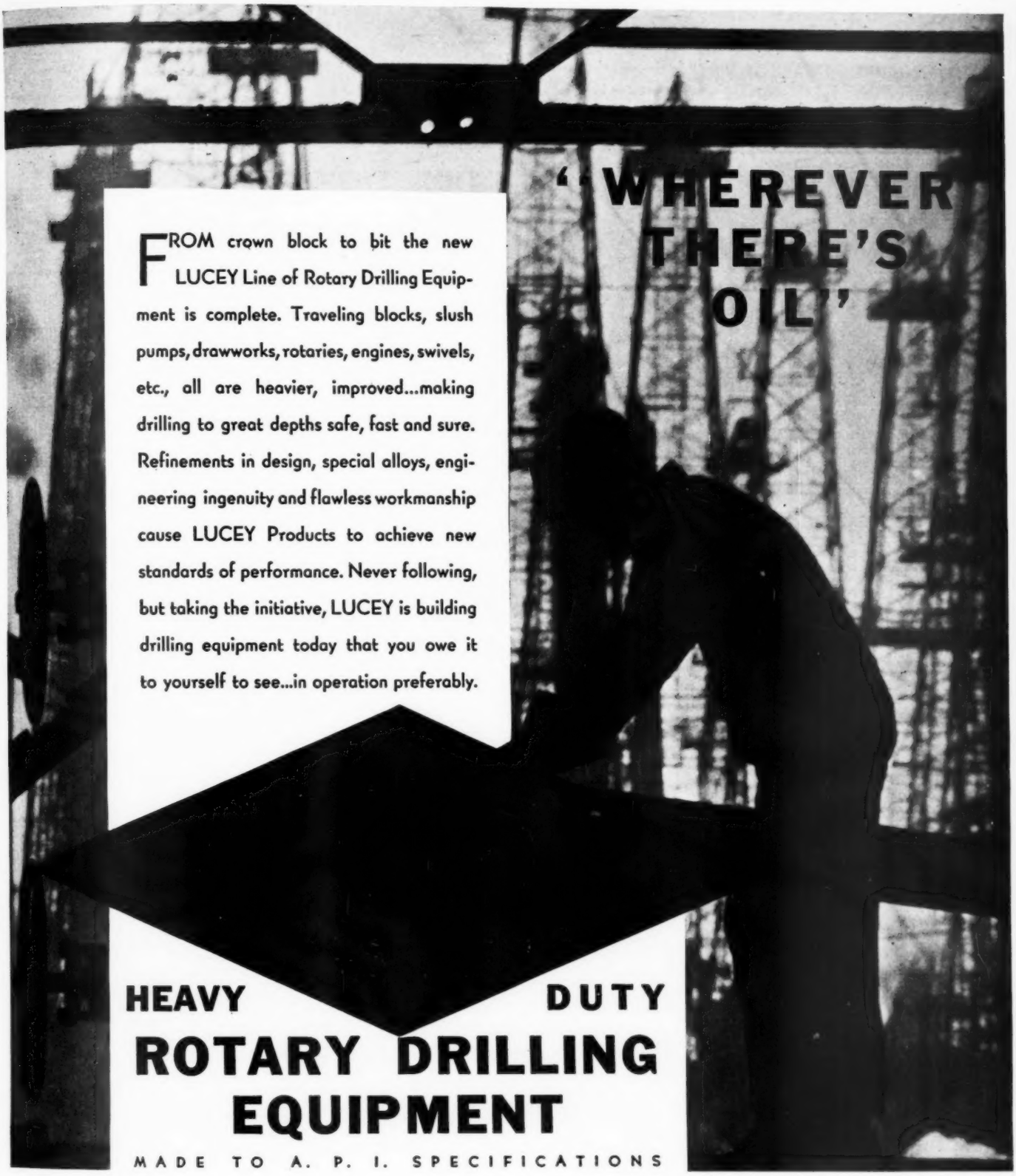
At this point the true flexibility of the process becomes evident. Even a casual inspection reveals that we have here four separate operations involved, each one an individual problem, but all co-ordinated into one process. The economizer and evaporator constitute an ordinary tube still unit for the production of vapors and a fuel oil residue. To increase fuel viscosity it is necessary to increase the quantity of steam, or in some other way to increase the percentage vaporized without cracking the residue. To decrease fuel viscosity one may increase fuel production, or the oil line temperature may be raised enough to cause mild cracking. If carefully done, this latter method will result in decreasing fuel percentage as well as viscosity. By the same token it is possible to operate so as to make an asphalt residue as a final product instead of a fuel oil.

The second operation involved is the cracking of the vapors in the converter. As can readily be seen this operation may be varied at will so as to secure the desired products and yields. This constitutes the only special piece of equipment in the Gyro Process, and represents less than 30 per cent of the total cost of the installation. The converter has a specially designed furnace intended to utilize in the most efficient manner the radiant heat generated by combustion of the fuel. Care is taken that the rate of heat absorption by the vapors in their passage through the converter is proportioned to the needs of the reaction. Thus in the first few feet heat is absorbed at a rate in excess of 75,000 B.t.u.'s per square foot per hour, but farther on this rate is dropped to that necessary to maintain the temperature of reaction. In the beginning of the development work when recirculation of flue gas was employed difficulty was encountered in utilizing all of the waste heat in the flue gases leaving the converter. With the improvements in furnace design mentioned above the same heating is now done with five feet of tubing which formerly required ten feet and the waste gases are insufficient in quantity to vaporize the gas oil required by the process.

The third unit in the process is the fractionating apparatus. For this purpose ordinary refinery equipment may be used. The heat abstracted in producing reflux has been utilized by converting the refluxer into a low pressure steam boiler. In this way sufficient heat is obtained, when added to that recovered in cooling recycle stock, to produce all of the steam used in all pumping operations and to evaporate the distillate in the rerunning operation. It is, therefore, apparent that fuel consumption figures quoted for this process include cost of steam and rerunning and due consideration should be given this fact in comparing with other processes.

The fourth part of the system is the gas recovery plant. For this work either compression or absorption may be used, but great care should be taken to return all of the product so recovered to the raw distillate produced. Due to the fact that it is almost 100 per cent unsaturated it possesses very high antiknock value, and it also requires treatment similar to that given the remainder of the distillate in order to produce a suitable motor fuel. Since the fixed gas comes off the lock box at almost atmospheric pressure it is saturated with motor fuel fractions and may run as high as five gallons per thousand cubic feet. Approximately twenty per cent of the distillate made therefore is recovered from the gas.

A feature of low pressure vapor phase cracking which appeals to the refiner who runs a high sulphur crude is the desulphurizing character of the reaction and the freedom from worry over corrosion problems. When cracking a high sulphur charging stock the distillate obtained will have a sulphur content of about 50 to 60 per cent that obtained



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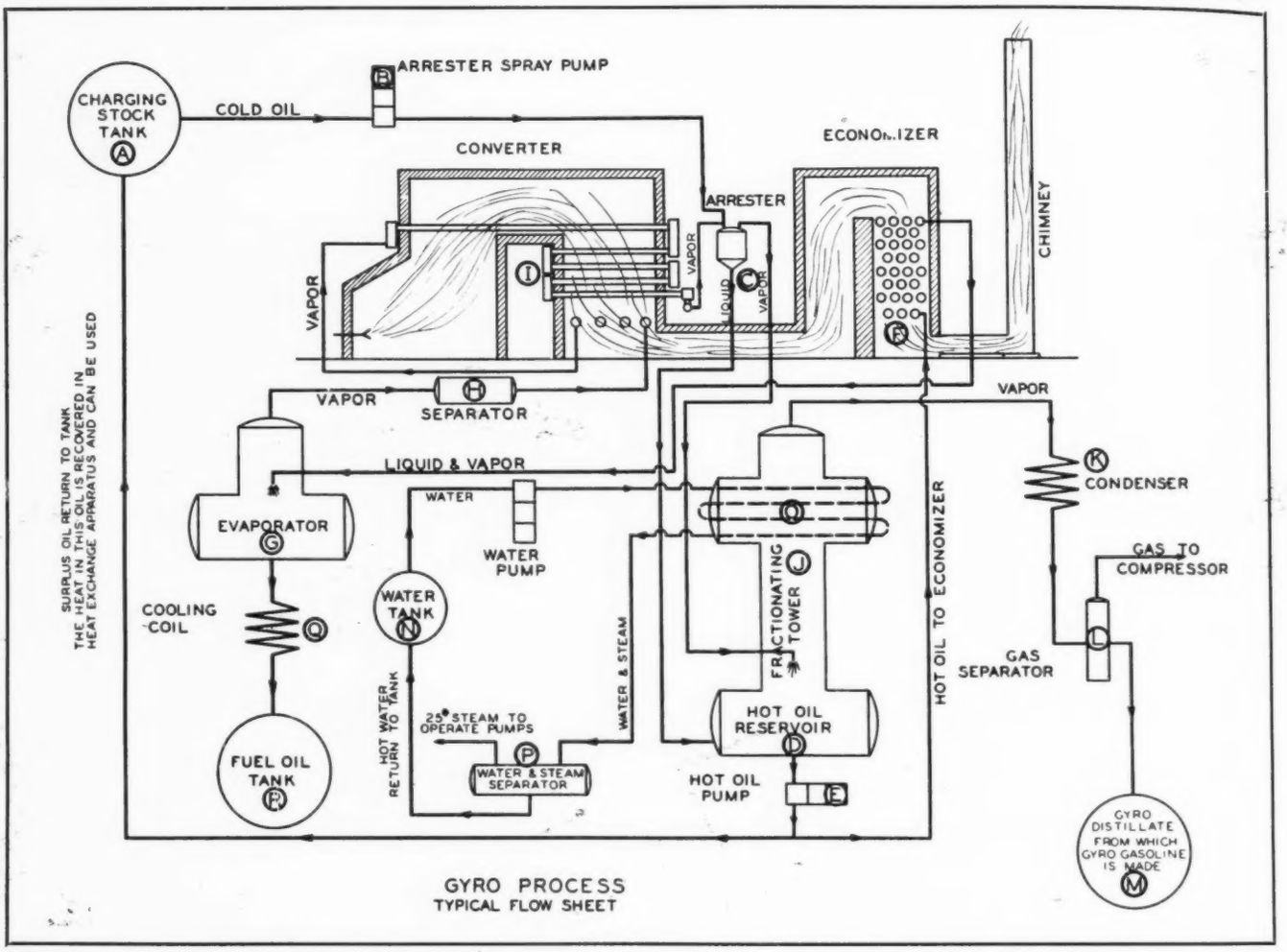
by producing the same boiling point distillate by liquid phase cracking. This appears to be due to the fact that a much higher percentage of hydrogen sulphide is split off which appears in the fixed gas. It would seem probable at first that this fact would lead to increased corrosion problems, but examination of the temperature gradient through the process reveals some interesting facts. It will be noted that in the economizer and evaporator the temperature is low enough to avoid material cracking and the consequent production of large amounts of H_2S. Corrosion in this part of the apparatus will not be great, therefore, especially since all of the light fractions have been removed and the entire body of oil passing through the economizer has been held for some time at temperatures between 475° and 550° F. In the converter the temperatures are right and sufficient H_2S is present to cause corrosion at a very rapid rate. The use of calorized steel or stainless steel parts, made necessary by the very high temperatures and oxidizing conditions in the furnace gases, effectively prevents excessive corrosion in this part of the equipment. Since the temperature is reduced to 600° F. or less in the arrester and is maintained below that figure for the remainder of the apparatus, little corrosion is encountered in vapor lines and towers. As is well known, it requires temperatures in excess of 600° F. or high velocities at lower temperatures to cause continued corrosion by hydrogen sulphide.



GYRO PROCESS
TYPICAL FLOW SHEET

In the first place it was the quality of the product alone that caused the refiner to turn to vapor phase cracking methods. It is, therefore, with considerable gratification that he can now reflect that he has a process which not only produces that same quality of product, but in addition produces it in quantities and at costs which compare favorably with the production costs of liquid phase cracked gasoline.

SERVICE of straight natural gas began recently in the area south of San Francisco and San Leandro, California. The new gas served by the P. G. & E. comes from Kettleman Hills and is 1100 BTU, twice the heat units of the manufactured gas previously served all northern consumers. The plans have been worked out by the P. G. & E. and the State Railroad Commission's engineering department.

The new service has begun without any immediate change in rates, the matter of rates now being before the Railroad Commission on application of the company to fix charges for the new type of service.

Crews which have had special training for the last few weeks will be moved into each locality as the natural gas is turned into the mains. These men, 450 in number, will make house-to-house calls, regulating appliances as the natural gas reaches the burners, and taking proper precautions to see that appliances are in satisfactory and safe operating condition for the new gas.

The first areas to be converted to natural gas will be the city of Santa Clara and peninsula towns and cities south of San Mateo, and the area served in the vicinity of Niles, Newark and Decoto.

San Jose was changed over to natural gas on Wednesday, September 25. Other localities south of and including Hayward and Daly City will follow as the trained men are released from the areas in which the change-over has been accomplished.

An Explanation of the Principles of

Internal Combustion Engines

By E. H. CROSSON, *Engineer, Franklin Valveless Engine Co.*

THERE seems to be a notion in the minds of many that the oil engine is a very complicated and mysterious machine, one that requires the attention of an expert engineer in order that it may be successfully operated. This notion is incorrect and we feel sure that a little study of the following explanation will convince anyone that oil engines are the simplest motors built and that any man of ordinary intelligence can easily understand and operate them.

Any internal combustion motor is nothing more than a gun, the chief difference between the two is that in the gun or cannon the projectile or cannon ball is thrown entirely out of the gun barrel and all the loading and firing is done by hand while in the gas or oil engine the motion of the piston in the cylinder which is used instead of the cannon ball in the gun is changed from a straight line motion to a rotary motion by connecting it to a crank by means of a connecting rod and all the loading and firing is done by the engine itself.

In the old style muzzle loading gun we place a charge of powder in the breech and ram the cannon ball down on it. If we ignite or set fire to the powder it will explode and force the cannon ball out of the gun. Now in the oil engine we place a charge of compressed air having a high temperature in the combusion chamber of the engine and inject oil into it. The oil and air forms an explosive mixture and as the compressed air is hot enough to instantly ignite the oil, an explosion at once occurs which forces the piston forward in the cylinder just as the explosion of the powder forced the cannon ball out of the gun barrel.

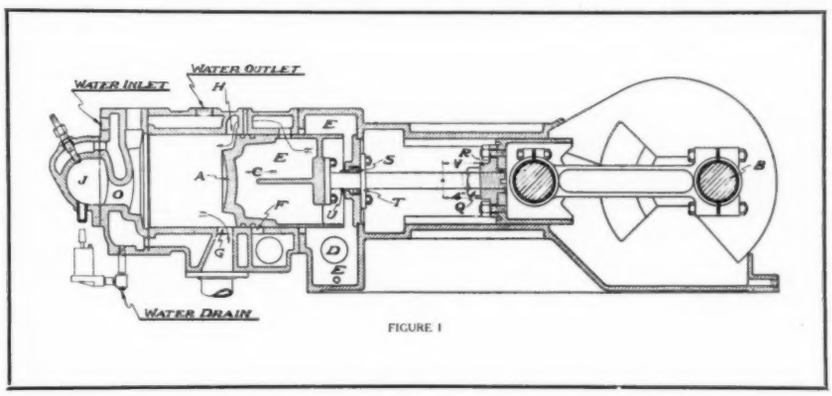


FIGURE 1

In order to understand how we get this charge of compressed air into the combustion chamber let us refer to Fig. No. 1 and Fig. No. 2 which are vertical lengthwise sections through the entire engine.

Now in Fig. No. 1 the piston A is shown in the end of the cylinder next to the crankshaft. It is easily seen that if the crank B is turning that the piston will be moved in the direction of the arrow C or toward the head end of the cylinder which is the end farthest away from the crankshaft and the one in which the explosions occur.

If there is a valve in the opening D then air can flow in and keep the space E filled with air as the piston moves back, but if no valve is used and the opening D is closed then no air can enter this space until the piston has traveled far enough to open the port F as shown in Fig. No. 2. When this port is opened by the piston air will flow through it into space E because of the suction or partial vacuum that has been produced by the moving back of the piston.

In some engines a valve only is used to admit air to space E. In some only the port F is used and in some a combination of both port and valve is used, but in either case space E will be filled with fresh air when the piston reaches the head end of the stroke as shown in Fig. 2.

As the piston will now start on its forward stroke it will at once close port F and as the valve D (if one is used) will now also close the fresh air in space E will be compressed until the piston reaches the forward center as shown in Fig. No. 1. Just before the piston reaches the end of its forward stroke it will uncover port G and allow the exhaust to escape. It also opens port H a very little later and this permits the air which has been compressed in space E to form 3 to 6 lbs. pressure to flow over into the cylinder and scavenge or blow out the burned gas remaining in it. The deflector on the end of the piston directs this flow of fresh air into the cylinder in such a manner as to prevent as far as possible any of its escaping with the burned gas.

The piston now starts on the back or compression stroke and at once closes the ports H and G. As no air can now escape it is almost all compressed into the combustion chamber J. The compressing of air always heats it so we now have the charge of hot compressed air in the combustion chamber and are ready for the injection of the oil into it to cause the explosion that will drive the piston forward. This is accomplished by means of a plunger pump K, Fig. 2, driven by a cam or eccentric L on the crankshaft. This eccentric is timed or set on the crankshaft so as to cause the eccentric rod M to strike the end of the pump plunger N, force it forward and inject the oil into the combustion space J when the piston is nearing the end of the compressing stroke.

Injecting the oil at this time causes a very high pressure (usually called an explosion) to be generated in the combustion chamber which acting through the port O and against the piston forces it forward.

As the crosshead P is securely fastened to the piston by the piston rod and is also connected to the crankshaft by the connecting rod it is easily seen that the forcing of the piston forward by the explosion in the combustion space will cause the crankshaft with the flywheels to turn or rotate.

The next thing to consider is how to control the engine. It is very plain that if the load on the engine is light but little oil will be needed to produce an explosion sufficient to keep it running, but if the load is increased the quantity of oil for each explosion must be also increased.

There is usually one or the other of two methods used to do this. One is to allow the pump to always have its full

length of stroke and at all times pump all the oil it can, but not allow more than the needed amount to be forced into the combustion chamber, this amount of course is to vary with the load on the engine. The other method is to increase or decrease the amount of oil by shortening or lengthening the stroke of the pump plunger. In either of these methods the controlling can be done by hand, but it is much better to use a governor and let the engine do its own controlling.

In the first method a by-pass valve A is placed between the discharge and suction of the pump, Fig. No. 3. While the pump plunger is being forced into the pump it will force the oil into the combustion chamber until the by-pass valve is opened and allows it to flow back through T into the suction of the pump. The by-pass valve is opened by the trigger or lever B which is pivoted near its middle in the end of the governor lever C. When rod D which is fastened to the eccentric rod forces the lower end of the trigger forward the upper end will force open the by-pass valve A against the resistance of the spring E. This spring closes the by-pass valve when the pressure of the rod D is released from the trigger.

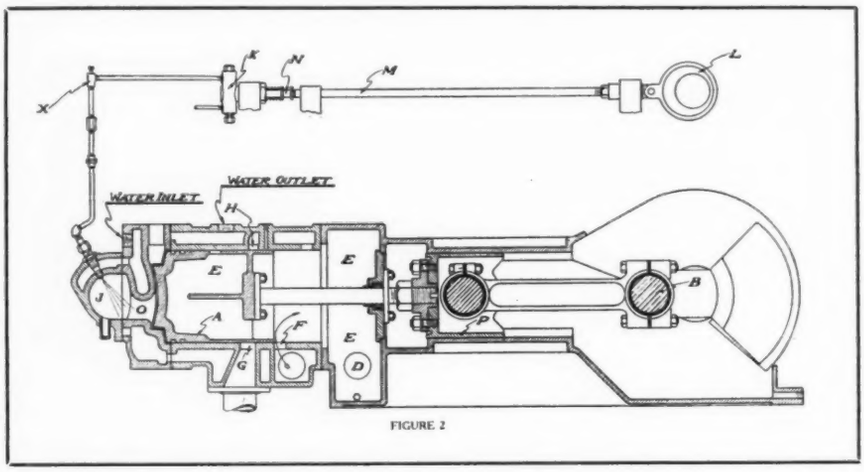


FIGURE 2

Now if the rod D is forced against the trigger at the same time the end of the eccentric rod F comes in contact with the pump plunger G, then the by-pass valve will open at the same time the pump plunger starts forward and all oil will flow through the by-pass valve and into the suction of the pump, but if the end of the rod D does not come in contact with the trigger until after the pump plunger has traveled part of its stroke, then the pump will deliver oil to the combustion chamber until the rod D strikes the trigger and opens the by-pass valve.

The time the by-pass valve opens in relation to the travel of the pump plunger is determined by the position of the governor lever C.

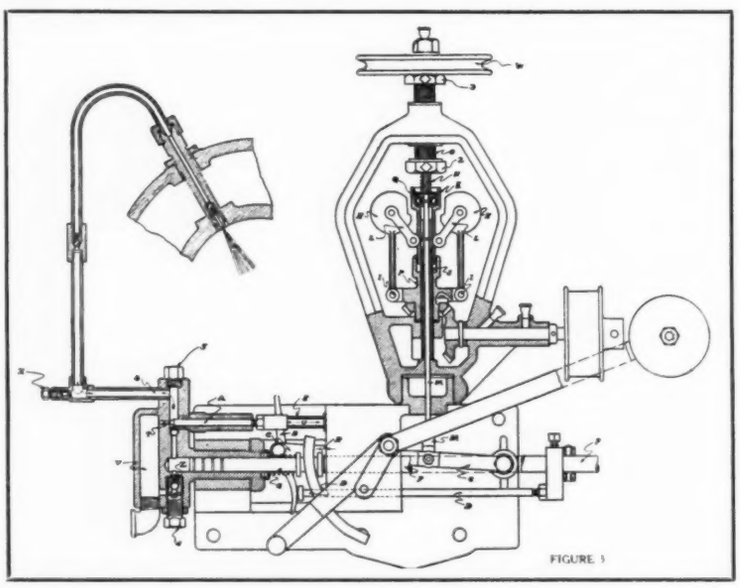


FIGURE 3

In Fig. No. 3, the end of the governor lever C which carries the trigger B is shown in about the middle of its travel up and down. The pump plunger has traveled the distance R which is part of its stroke and the rod D is just coming in contact with the trigger B. Up to this time the pump plunger will have forced oil through the discharge pipe S into the combustion chamber, but as the rod D is now by means of the trigger B opening the passage T by forcing the by-pass valve A in the direction of arrow U all oil for the balance of the stroke of the plunger will not be forced through the discharge pipe S, but will flow through passage T into the inlet or suction of the pump. Now because of the curved shape of the lower end of the trigger it is easily seen that if the governor lever is dropped low enough the rod D will not strike the trigger at all, the by-pass valve A will not be opened and all oil delivered by the full stroke of the pump will be forced into the combustion chamber, but if the governor lever is raised to its highest position the rod D will strike the trigger at the same time the eccentric rod D strikes the pump plunger and all the oil delivered by the full stroke of the pump will flow through the passage T into the inlet V and none will be forced through pipe S to the combustion chamber.

The engine is therefore controlled by the raising and lowering of the governor lever.

This is done automatically by the governor which consists of two or more weights or balls H, Fig. No. 3, having arms pivoted at I to a head which revolves around shaft J. A sleeve K free to slide on shaft J is connected to the weights by links L which are pivoted at each end. The governor lever C is connected by a rod or stem M to a collar which rides on top of the sliding sleeve. A coil spring N having its tension adjustable by means of a screw O bears on the collar.

The revolving head P with the weights, links and sliding sleeve are free to revolve and are driven by the engine through a belt or gears or a combination of both, therefore the speed of these revolving parts varies with the speed of the engine.

Now suppose the engine and consequently the governor are not running, then the tension of the spring will hold the collar Q, sliding sleeve K and governor lever in their lowest position and the weights H in their innermost position. With the governor lever in this position the pump will force its full supply of oil into the combustion chamber, but if we spread the governor weights apart we will through the action of the links L, sliding sleeve K and rod M, raise the governor lever and allow part of the oil to flow through the by-pass valve as has been explained.

It is hoped that this story will convey to the reader a clearer idea of the internal combustion engine.

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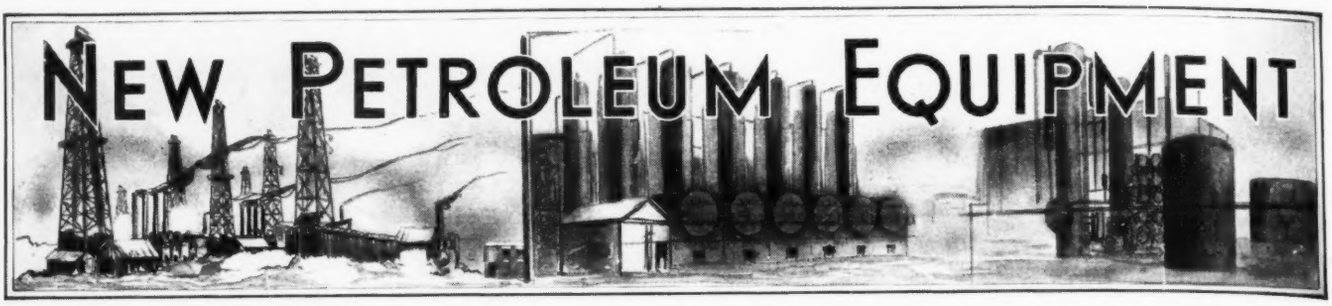


ANNOUNCEMENT of the Pittsburgh Equitable Meter Company that it will establish a branch factory in Tulsa as one important step in an expansion program meant acceptable news to A. J. Kerr, its district manager, who has been interesting himself in such a proposition for the past two years.

A. J. Kerr

The site for the new plant is located on the Sand Springs highway just north of the old inner compression tube factory. It has a frontage of 250 feet with an equal amount of trackage in the rear. The land was bought from C. A. Mayo and C. W. Day. John Chapman, industrial realtor, handled the transaction.

That the company has fortified itself for continued expansion in the mid-continent is indicated by the fact that its factory building will be 50 by 150 feet. Mr. Kerr states ground will be broken very soon and the plant completed and in operation after the first of the year. Investment in ground and building will total $50,000, which is exclusive of the equipment. It will be of the latest modernistic industrial design, very attractive in appearance, Mr. Kerr states.

The company is also constructing a new building adjoining the present plant in Pittsburgh. The plant here will be devoted to the manufacture and servicing of Emco gas meters and regulators and Pittsburgh gasoline, oil and water meters. Location on the direct route to the oil fields affords the company many advantages.

THE new Frick-Reid Supply Store at Houston, Texas, is located at 2330 Quitman St., the main artery of traffic connecting Houston with the Humble, Dayton, Liberty, Goose Creek, Hull and Barbers Hill fields.

The structure is an Ideco steel building, 36 by 110 feet, with 16-foot walls. The inside of the building is so arranged that any class of material can easily be located in order to give the customers prompt service.

New Bulletin by Cooper-Bessemer

The Cooper-Bessemer Corporation of Mount Vernon, Ohio, has distributed bulletins on the new Type-80 Gas Engine Compressor.

This is a four-cycle horizontal single-acting direct drive compressor, which is claimed by the makers to eliminate smoking or throwing of oil with the new breather compartment. The breather is completely closed and has no outlet into the engine room. Air is sucked into the intake pipe from outdoors, passes up through the body of the main bed, past the front face of the piston, and then to the mixing valve, through a connecting pipe. This system cools the piston, removes vapor or smoke caused by combustion and prevents fogging-up of the engine room.

THE Bovaird Supply Co. of Tulsa, Okla., announces the distribution of the new Bovaird Split-Slip type tubing elevator. This elevator is the result of innumerable field and shop tests extending over a period of two years, and is offered with the utmost confidence in its ability to perform the services for which it is designed.

The outstanding feature is the use of tapered slips with a positive release that is independent of the slips. This is accomplished by having the two halves of the bowl rock away from each other when the load is released.

Only one size, viz.: 3-inch, elevator is made, as one size handles, by the employment of removable and interchangeable slips, 2-inch, 2½-inch and 3-inch tubing, either regular or upset.

There are four slips to a set. They have horizontal rows of teeth for engaging the tubing and they are specially heat treated and hardened. Extending above the body of the elevator and slips are two lugs, called automatics, concaved to fit the tubing closely and not to pass the coupling. These automatics are also removeable and interchangeable and a set is required for each different size and style of tubing. When not engaged on the tubing the slips are held up in the tapered bowl by coil springs and away from the tubing by shoulders on the automatics. This allows the tubing to turn freely when screwing in or out and avoids all wear on the teeth of the slips.

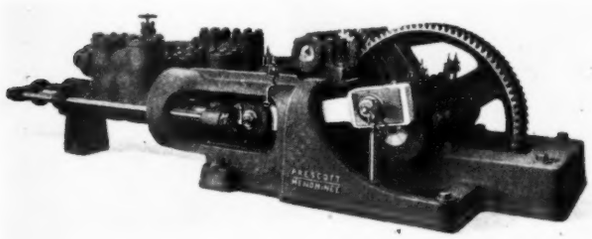
The entire structure, except the bails, which are of the usual type and are hand forged, is made of special analysis steel castings, specially heat treated for the service required.

TRACKSON McCormick-Deering crawler tractors have assisted in the pipe line construction work of the Ohio Fuel Gas Company, according to D. M. Wilson, superintendent of their operations. They employ three Model DH heavy-duty units equipped with Seminole pipe handling booms and two Motel LH outfits, one of which is equipped with an Ersted-Willamette hoist, which are used for stringing pipe along the right-of-way.

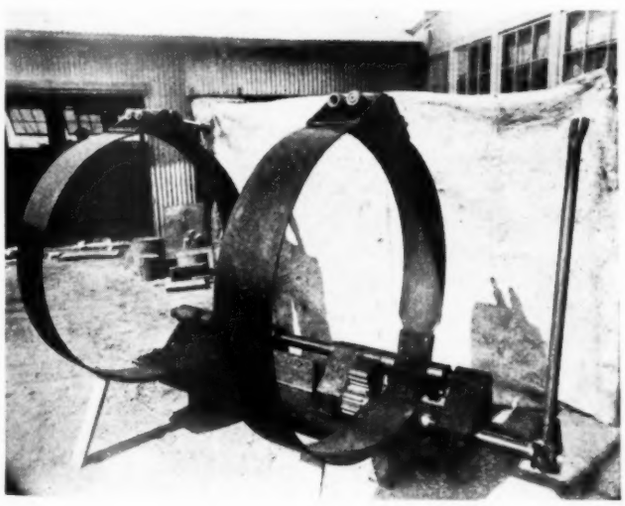
At present these machines are employed in the construction of a new forty-five mile eighteen-inch pipe line in southern Ohio, where they are encountering some of the worst country in the state. Trucks haul the pipe as near to the right-of-way as they can go, then the lighter Model LH Tracksons pull it up the sides of hills and over the rough, rocky sections where there are no highways. Despite the extreme ground conditions, they are pushing the job ahead at a rapid rate, replacing a number of teams and facilitating the handling of the heavy pipe.

The Model DH Trackson McCormick-Deerings with the Seminole pipe handling booms are used for stabbing and lowering in, and replace a big gang of men on these operations.

Wagner Electric Corporation announces the removal of two branch sales offices. The Milwaukee sales office and service station has been moved from 501 Broadway to 525-27 Broadway. The St. Louis sales office has been removed from 505 Shell Building to 909-9 Plaza Olive Building. Those removals were necessitated by increased business requiring more space.



The Prescott Company has distributed catalogues describing the field pump illustrated above. These pumps are designed to handle from 4,000 to 6,000 barrels of oil daily.



A view of a new geared rotary brake being introduced by the MacClatchie Mfg. Co. of Compton, Calif.

The Smallamatic

THE introduction of air or gas to the well to lift the oil is controlled by the fluid level in the well. The device which accomplishes this, called the Smallamatic, consists of a small diaphragm operated pilot valve, which in turn operates a main diaphragm valve for the admission of air or gas. The Smallamatic has been in successful use by the Tidal Oil Company in eastern Oklahoma for over two years.

Three New Ditching Machine Bulletins

The Parsons Company, Newton, Iowa, has published three pieces of trade literature, all of which pertain to their line of ditching and trenching machinery. Parsons Number 21 offset-boom ditcher is amply described and is illustrated performing work of several types. Parsons Model 40 excavator, which is also treated in one of the bulletins, is designed to handle trench work between 24 and 42 inches in width to the depth of 18 feet.

What is claimed to be the largest full crawler ditcher made is Parsons Model 31, which is designed to dig ditches from 18 to 36 inches wide up to 12 feet in depth. All three of these lines of equipment are distributed by the Leland Equipment Company of Tulsa in the Mid-Continent area.

New Garlock Catalog

"Save the Oil", is the title of the beautifully designed and amply illustrated catalog by the Garlock Packing Company of Palmyra, N. Y.

This catalog illustrates how a material saving in oil consumption may be attained by the proper application of Garlock Oil Return Packing on various types of power units. The different packings as illustrated in this booklet are not new or in an experimental stage but are said to be the result of years of intensive study and development by Garlock.

METERS METRIC

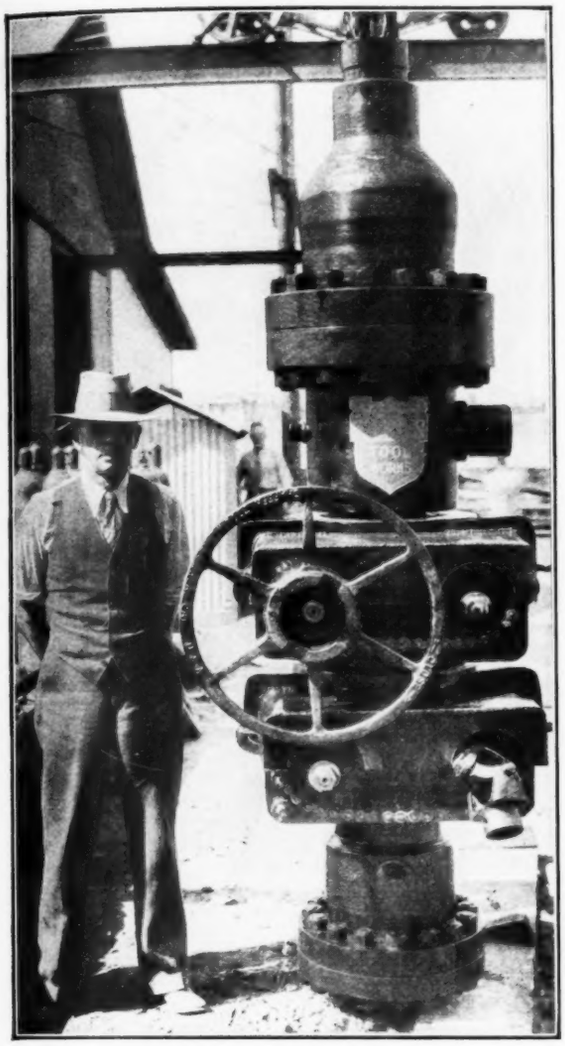
Accuracy of Orifice Measurement *established* 4163 Years Ago

TABLETS of stone, previous to 2234 B.C., tell how Chaldean astronomers used the ORIFICE principle so accurately that their computations of the synodic and periodic months fell short of our modern time by *less than five seconds.*

The Chaldeans' method was simple. By comparing the quantity of water discharged through an *orifice* during the time occupied by the sun crossing the horizon the morning of the equinox, with the amount discharged through the same *orifice* at the next sunrise, they discovered that the amount discharged between the two risings of the sun was 720 times the amount discharged during sunrise on the equinoctial morning. They thus inferred that the sun's orbit measured 720 times its disc, and from that they derived a unit to measure space and *time.* Today, 1929 A. D., Metric *Orifice* Meters set the standard of accuracy in oil and gas measuring. Use of the time-honored *orifice* principle alone is not the reason; 38 years of meter-making experience, good materials, expert workmanship, and always-available service from the largest manufacturer of orifice type meters insure dependable, economical measuring. ***Write for Bulletin No. E-2.***

METRIC orifice METERS

METRIC METAL WORKS
of the American Meter Company—Inc.
ERIE • PENNSYLVANIA • U.S.A.



Shaffer Tool Has New Control Head

SOLID steel flanges four inches thick, bolts two inches in diameter, and gaskets of special metallic alloys are required to hold the five thousand pounds pressure specified in an order for Warren control heads and other high pressure fittings now going through the shops of the Shaffer Tool Works here.

Actual tests in the shop with a specially built hydraulic compresser pump which builds up a cold water pressure of five thousand pounds per square inch have proven the need of extra thick flanges and alloy steel in the studs and bolts, according to Shaffer engineers.

Extra pressures encountered at Kettleman Hills, and two serious blowouts in that territory, have influenced petroleum engineers and others responsible for drilling operations there to demand unusual precautions and tests for all material to be used in that field, which is considered the most treacherous now being developed.

An idea of the size and construction of some of the fittings required can be realized by a glance at the photograph, which shows a cellar assembly made by the Shaffer Tool Works, ready for shipment to the Standard Oil Company, for use at Kettleman Hills. W. D. Shaffer is shown alongside the fittings.

The assembly includes two Shaffer Control gates, one fitted to close around drill pipe, and the other to function as a drilling valve, closing open hole. The design is so compact, according to the manufacturers, that the two five thousand-pound gates occupy approximately the same cellar room as one of the conventional type valves.

Each set-up of this size, 9-inch, weighs nearly four tons, one such order each week being included in the regular schedule at the Brea plant, in addition to other business, American and foreign, in casingheads, flow beans and high pressure equipment for all parts of the world.

WM. H. JACKSON, purchasing agent for the Axelson Machine Co., and connected with that organization for the past 19 years, has been made special supervisor of the Axelson Aircraft Engine Co. and director of purchases for both concerns.

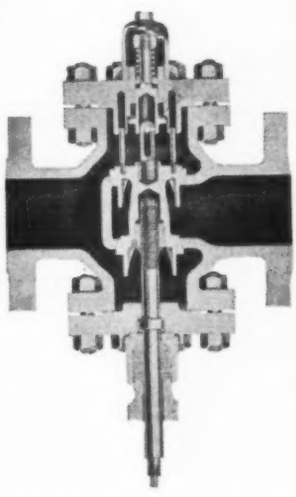
Raymond E. Imhoff, assistant purchasing agent for the Axelson Machine Co. for the past six years, becomes purchasing agent for this company.

Leslie Salow, formerly with the Gallagher Tank Co. and the Western Pipe and Steel Company, becomes assistant purchasing agent to Mr. Imhoff.

The creation and maintenance of the office of assistant purchasing agent is in line with the Axelson Machine Co.'s policy of maintaining audience facilities available at all times to salesmen and other representatives who call.

Steam flow meters, Bulletin No. 162, by The Foxboro Co., Foxboro, Mass., is an illustrated bulletin describing the new Foxboro steam flow meter and the method of pipe layout for its installation. Steam flow coefficients are graphically shown, and the theory of velocity meters is discussed.

Kerotest Develops Unique Type of Throttle Valve



THERE has been a long felt want in the oil fields for an improved type of throttle valve that would provide a quick, positive release of any accumulated pressure when the valve is in the closed position.

After extensive development work, the Kerotest Manufacturing Company of Pittsburgh have designed a new type of cast steel valve for this purpose which it is claimed will not only perfectly regulate all pressures but also provide a quicker opening and a more sensitive control. It has already been successfully applied in the oil field under actual working conditions at both high and low pressures.

As can be noted in the sectional view, the Kerotest Throttle Valve is a radical departure in design from the usual method. The double seating arrangement maintains an exact equalization of pressure as well as preserving a perfect balance.

The triangular openings of the valve proper admit of very sensitive control. The stem is of the non-rising type, having no operating threads exposed to damage or interfering with the ease of operation. The release valve is automatic and positive in operation, opening at all times when the valve is full closed.

Literature and full information will be sent by the Kerotest Manufacturing Company of Pittsburgh, Penna., upon request.

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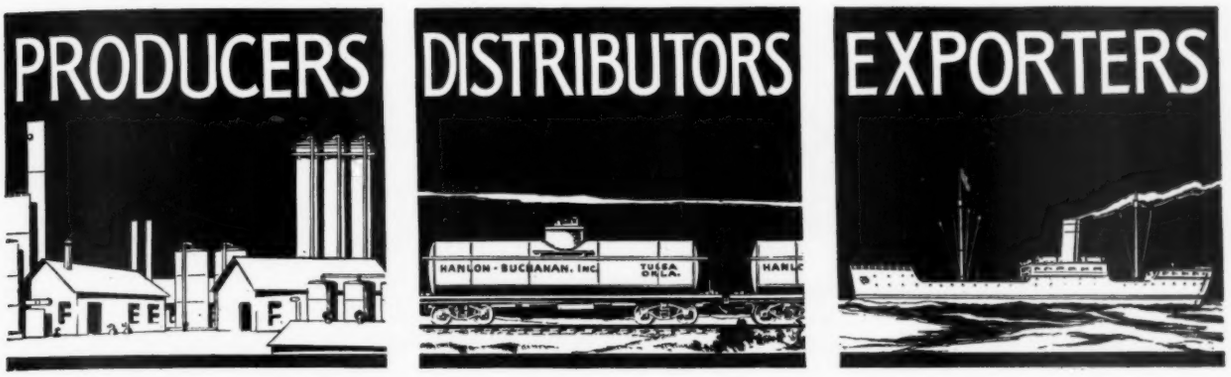

Especially processed products of Natural Gasoline

and

Natural Gasoline in all the conventional grades

Our facilities, including a complete processing plant and terminal at Good Hope, Louisiana (New Orleans port), enable us to handle any order from

A CAR TO A CARGO

CHANAN, INC.

TULSA, OKLAHOMA

ESPECIALLY PROCESSED PETROLEUM DERIVATIVES

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Adams Appointed Service Engineer

WILSON-SNYDER MANUFACTURING CORPORATION, Pittsburgh, Pa., builders of high pressure Slush Pumps, announce the appointment of J. W. Adams as special traveling service and engineering representative. Mr. Adams has many years' experience in oil field engineering. During the past year he has given special attention to slush pump operation and recently spent considerable time at the factory in Pittsburgh for the purpose of becoming thoroughly acquainted with every detail of Wilson-Snyder Slush Pumps.

New Emsco Bulletin

The Emsco Derrick & Equipment Company, Los Angeles, California, has distributed Bulletin Number 28 on Gardner-Denver slush pumps. The new type pump is said to adapt itself excellently to the requirements of the oil field in rotary drilling, cementing, and oil line work.

The totally enclosed construction keeps all mud and dirt from the working parts and the system of flood lubrication insures a smoothly operating unit.

The Emsco Derrick & Equipment Company has also distributed Bulletin Number 6 DB concerning sucker rods and allied equipment. This bulletin contains an exhaustive explanation of the scientific and practical investigations which tend to the continual improvement of D. & B. sucker rods.

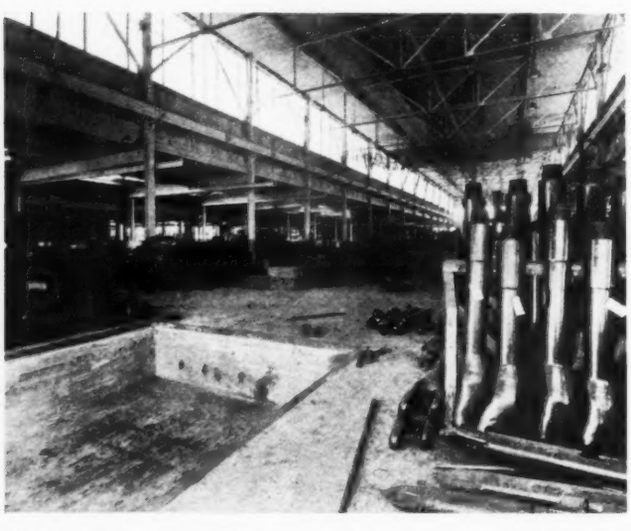
Naylor Spiral Pipe Bulletin

This is a profusely illustrated and beautifully printed piece of trade literature. It explains in detail the new engineering features involved in the manufacture of Naylor pipe. It contains an abundance of illustrations, which portray exceptional conditions in the oil industry. Copies will be sent upon request.

Axelson Is Building Again

Contract for a new two-story office building, 32x130 feet, of hollow tile with stucco exterior, has been awarded by the Axelson Machine Company of Los Angeles. The new office will be several times larger than the entire original Axelson factory of some thirty-five years ago.

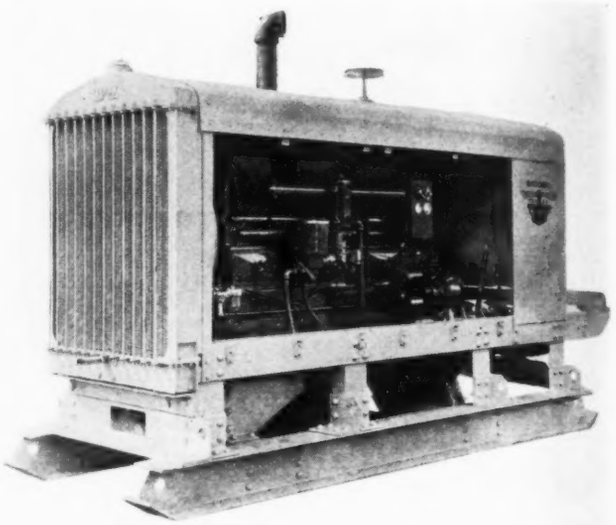
The petroleum pipe line systems of the United States have a total mileage of more than 100,000 and represent an investment of above $3,000,000.



Model factory conditions embodying most recent ideas of light and air are illustrated in this view of a section of the Byron Jackson Co. oil tool division, Los Angeles, Calif.

New and Larger Climax Drilling Engine

THE Climax Engineering Company of Clinton, Iowa, is introducing its new 6-cylinder, 150 horsepower natural gas and gasoline drilling engine which has just been developed for deep cable tool and medium heavy rotary work. It will be known in the trade as the "Drillmaster", and it is



the fourth Climax drilling engine, completing a power range of 65, 85, 130 and 150 horsepower.

This new "Drillmaster" engine has more power than the well-known Climax Paymaster, and it embraces many improved features in design and equipment. Its valve-in-head design permits of large water passages for better cooling of blocks, heads and especially around the valves, which is particularly essential for operation on natural gas. This ample cooling preserves the life of valves, valve seats, gives sustained power capacity, and reduces the hazards of bad water. Rocker arms are fully enclosed and are lubricated by pressure from the main system.

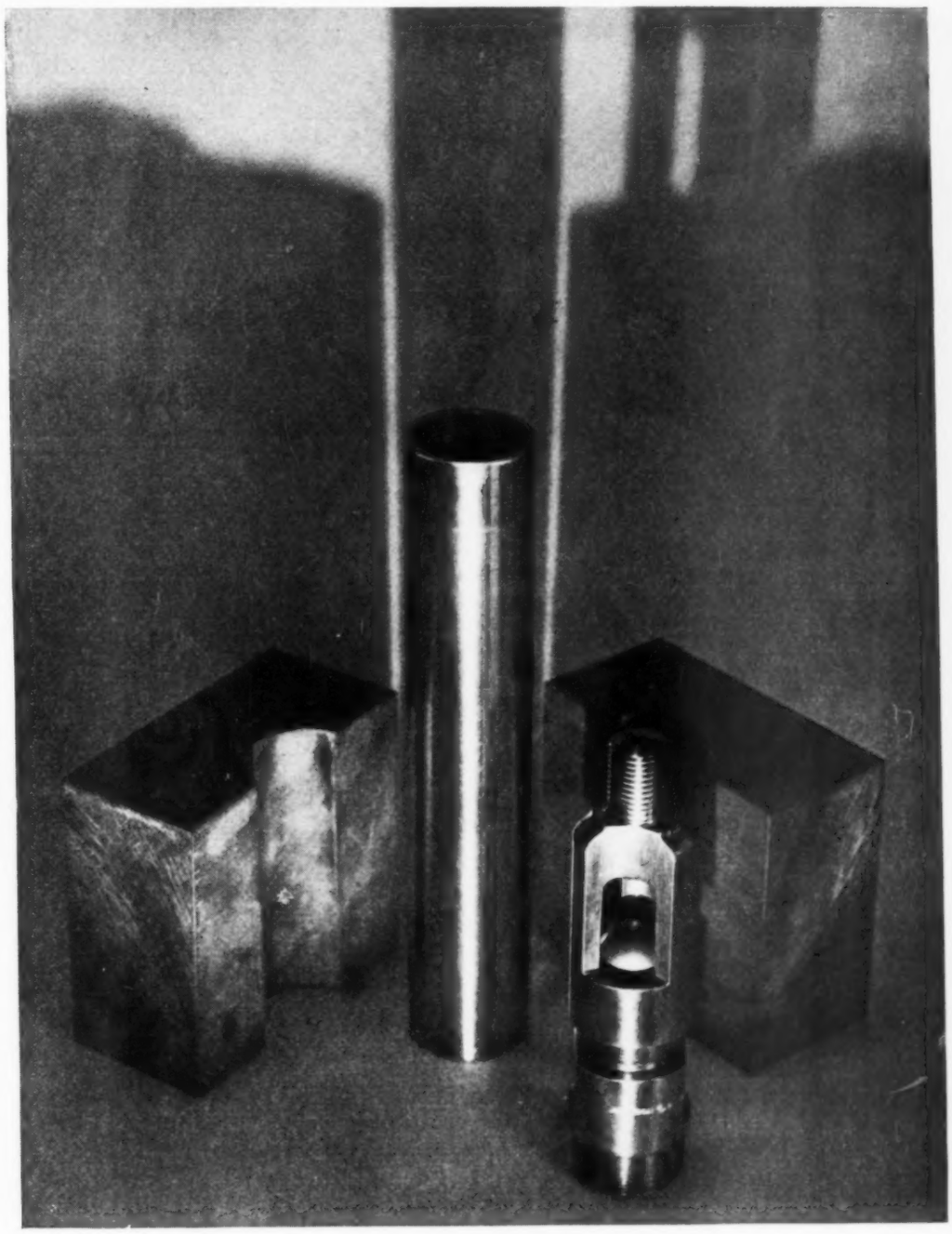
Advanced internal combustion engineering is evident in the design of this engine, which is one of the new Climax Blue Streak Series. A combination of proper valving, cooling, manifolding, carburetion and combustion chamber design, results according to tests, in from 10% to 12% increase in horsepower capacity as compared with L-head engines of similar displacement, with the added benefit of approximately 10% saving in fuel. A further result of this new design is shown in the ability of the engine to pull down under heavy load with marked freedom from "pinging."

JUST off the press, and now available to the trade, is an attractive 12-page printed bulletin covering the Louis Allis "Explosion-Proof" or Type E electric motor, made in Milwaukee, Wis.

The Louis Allis Type E motor is said to be the only "explosion-proof" motor of reasonable size and weight approved by Underwriters' Laboratories for operation in explosive atmospheres. Consequently it brings the safety and economy of individual motor drive to many hazardous industries for the first time. It enables machinery builders to offer and enables machinery users to buy, complete *motorized* machines—for the safe manufacturing, use and handling of gasoline, alcohols, ethyl acetate, toluene, benzol and other volatile flammable liquids.

Since the American petroleum industry started in 1859 it has drilled 763,095 oil wells.

UNRETOUCHED PHOTO



Pump parts

THAT FIT

the high quality of Axelson products and the excellent service derived from same, together with the sincere efforts put forth to serve Axelson customers in a satisfactory manner, have resulted in a constantly growing demand for these pumps throughout the world. All parts are fitted to a most exact standardized size, giving complete interchangeability—a most desirable feature, especially where transportation is of primary importance.

THERE IS NO ECONOMICAL SUBSTITUTE FOR QUALITY

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A *Axelson*

WORKING AND STANDING VALVES

A variety of Axelson working and standing valves is offered, permitting of any desired pump combination to meet the peculiar well conditions.

Our new catalog, No. 110, just published, will be mailed upon request.

Axelson Machine Company

P. O. Box 337 Los Angeles
Tulsa St. Louis
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Mid-Continent and Eastern Distributors
Frick-Reid Supply Corporation

INTERCHANGEABLE LINER PUMPS

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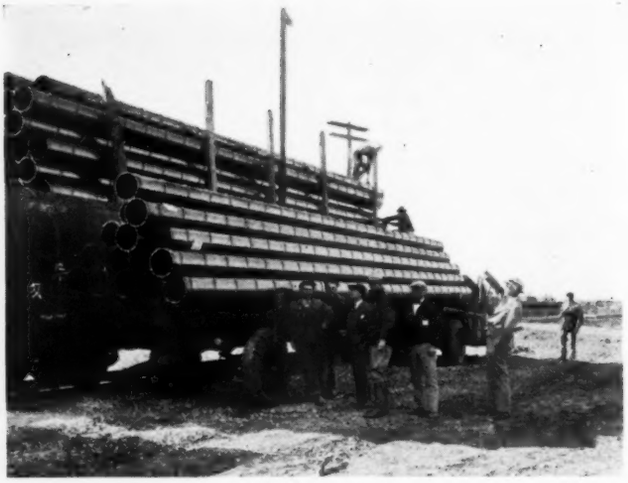


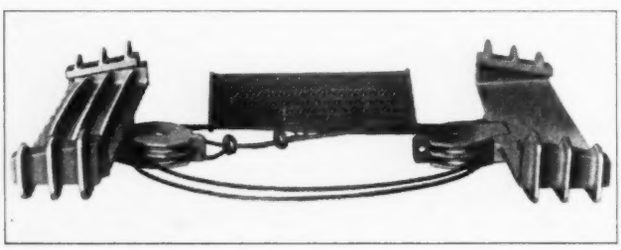
THE above picture shows a fairly good-sized load of Naylor pipe being handled at Oklahoma City. The one truck carries 600 feet of pipe.

The spectators checking up on this are (in foreground) "Spider" Allen of the Naylor Pipe Co., Ralph Risser, chief construction engineer of the Shell Petroleum Corp.; P. A. Foor, district foreman of the Shell interests in the Oklahoma City district, while the gentleman who is giving the well-known Indian hailing sign is T. G. Laney of the Moorlane Co., Tulsa, Okla.

THE Houston Oilfield Material Co. of Houston, Texas, has been made distributor for the new Black Gold oil and gas separator manufactured by Camp-Morgan Co. of Tulsa, Okla.

Oil Well Supply Markets Belt Stretcher

THE Oil Well Supply Company of Pittsburgh, Pa., is marketing the new Horner-Mildren Belt Stretcher. This stretcher, which is made in one size to accommodate belts 14 inches wide and under, embodies construction and operating features that have proven highly successful in all fields. The equipment consists of two body parts with a two-sheave pulley attached to each, a wedge for each body part and a



section of ¼-inch or 5/16-inch wire rope. The ends of the wedge are drawn into the body. Hollow embossments on the sides of the wedges engage with the belt, giving secure grip on the belt when the tightening process begins. Operation of the belt stretcher is extremely simple. The ends of the belt are placed in the body of the stretcher and the wedges are inserted. The dead end of the wire rope is fastened to some solid object, such as a sill or belt house, and the engine is started. As the belt travels the ends are brought together, by the action of the tackle, ready for the application of a belt clamp.

The left part shows the wedge in place. At the right the wedge is removed and is shown in the center.

THE Vulrox Corp., of St. Louis, Mo., announces the opening of headquarters in the Kennedy Bldg., Tulsa, for its Petroleum Industries Division, to market Vulrox, a product for protection against corrosion. Robert Burnett, former research engineer, Humble Oil & Refining Co., is manager and branch offices have been established in Houston and Los Angeles.

The company is comprised of engineers familiar with corrosion problems. It maintains a research laboratory and offers its service for consultation and survey.

Vulrox is a synthetic rubber product with a high dielectric strength. It is claimed the product is inert to all commonly encountered corrosive reagents, is pliable and bonds perfectly with steel as well as with all ferrous and non-ferrous alloys. Vulrox is made in sheet, laminated, semi-solid, pressed and dissolved form and is all cold working.

New Safety Loading Equipment

INTRODUCTION is being made of a new type of tank truck and car safety loading equipment by the J. A. Campbell Company, natural gas engineers, Long Beach, Cal.

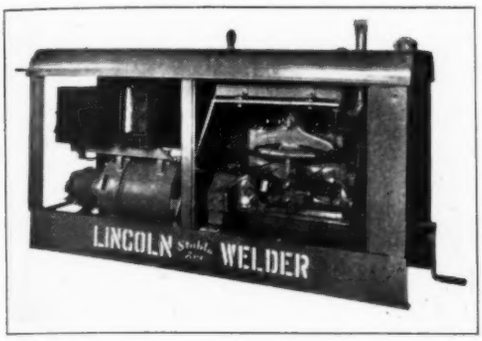
It is known as C. & B. loading equipment and is divided into two groups: A loading head which normally remains at the loading rack, and secondly, the tank truck or car equipment, consisting of an adapter ring or bushing, a cover plate and a sealed level gauge, all of which latter equipment is normally attached to the tank.

The manufacturers claim that with this type of loading equipment, hazards due to the escape of gasoline vapor during the loading of tank trucks or cars, are minimized. They further claim that when used in connection with suitable vapor-recovery apparatus, it will soon pay for itself in gasoline saved from the vapor which would otherwise be wasted. Bulletin No. 5, just issued by the concern, gives full details and may be obtained upon request.

The above scene doesn't look like pipe line country, but it does show a Barber-Greene ditching machine doing its stuff under the balmy skies of California.

New Lincoln Waukesha Driven Welder

THE Lincoln Electric Company, Cleveland, Ohio, has recently introduced to the trade a new model gas engine driven welder for use where electric power is not available. The new model welder is of 200 amperes N. E. M. A. rating and is powered by a 4-cylinder Waukesha engine, operating at 1,500 r. p. m.



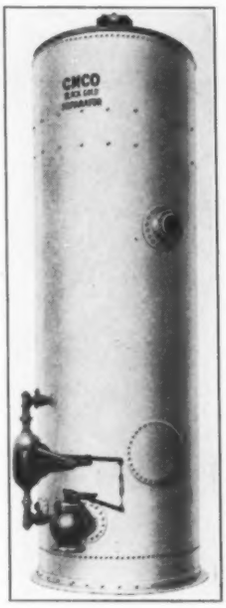
The latest improvements which are featured in the new models of Lincoln gas-engine driven welders are included in this new model. An automatic idling device is incorporated which automatically reduces the speed of the gas engine when welding operations cease, and automatically accelerates the engine to proper speed as soon as welding is started. It is estimated that this automatic idling device will reduce fuel consumption approximately 25 per cent, as well as considerably reducing wear in the welder, which will permit longer life of the equipment.

Another feature of this new model welder is the complete protection afforded the machinery by the welded steel canopy which totally encloses the outfit.

HERCULES TOOL CO., Tulsa, Okla., has sent to the trade its catalogue No. 1 which contains much interesting data, and several excellent illustrations of the company's products.

THE accompanying illustration shows the new Black Gold separator which is being introduced by Camp-Morgan Co. of Tulsa, Okla. This firm, composed of C. F. Camp and Jim Morgan, was organized recently to furnish a sales vehicle for the separators and the Neilan-Shumacher line of pressure regulating equipment.

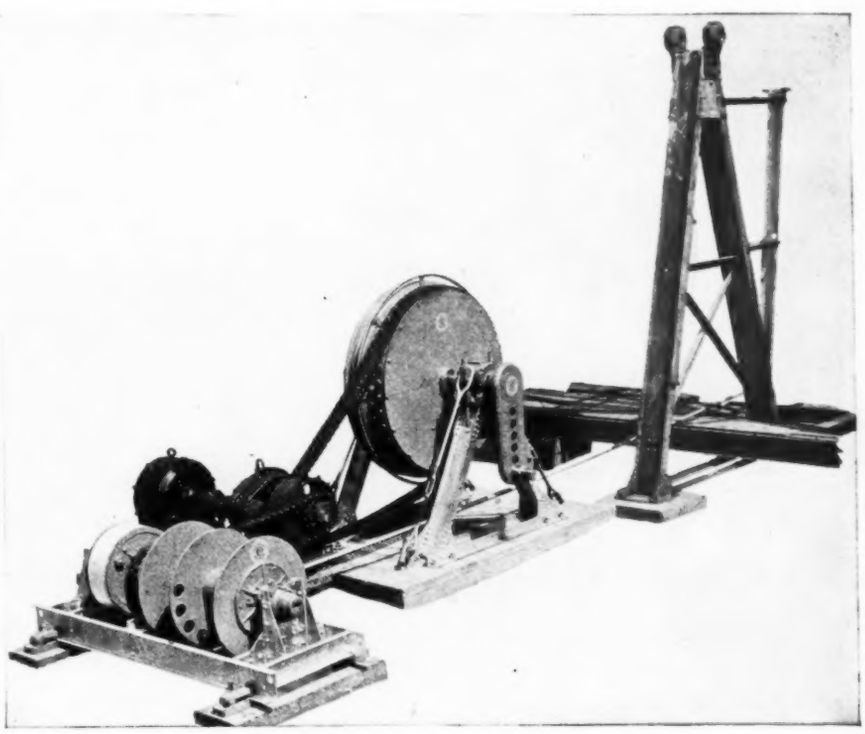
The Black Gold separator is constructed with Taylor forged steel nozzles, rotary ball bearing valves, and the Tulsa Type mist extractor. The separator is built to the specifications of the A. S. M. E. code.



The Ideco Now Has Chain-Driven Rig

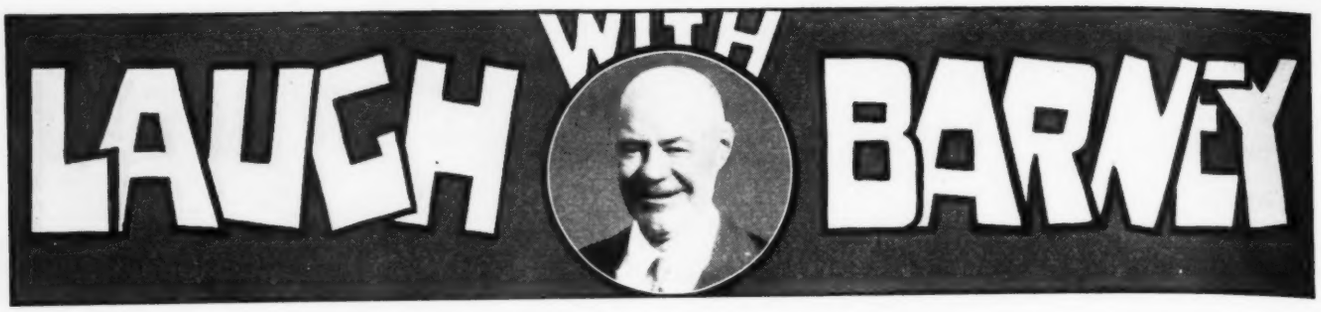
ON a new chain-driven rig, Ideco has eliminated belt trouble by using a chain for driving the crankshaft and offers a portable, easily moved unit that is foolproof and 100 per cent salvable.

The rig designed for deep drilling and pumping use, is made entirely of steel and is similar to the standard rig. It consists of an Ideco reduction gear drive, crank, chain wheel, "A" frame jack posts, "A" frame-Sampson and Headache Post, walking beam, pitman and crank counterbalance. Provision is made for installing a chain-driven sand reel if desired.



The reduction gear unit has 5 to 1 Herringbone gears and roller bearings, making it quiet in operation and unusually rugged and powerful. The shaft is easily adjusted vertically to different motor heights. The motor rails will fit any motor. Lubrication is by splash feed. This unit is self-contained and entirely enclosed. The steel bed plate mounted on slide rails allows lateral adjustment to maintain proper chain tension. The unit can easily be changed from right to left-hand drive in the field. A flexible coupling between the motor or engine used for power, absorbs the shock of starting and stopping.

The chain wheel is made up of a double tooth sprocket mounted between circular plates and welded to a hub that can be fitted to any standard rig iron shaft. An Ideco deep V double tug rim is provided for use in drilling and clean-out work where bull or calf wheels are used. A bull rope guard placed between the sprocket on tug rim protects the bullrope from chaffing. When tubing hoists are used for production purposes, a sprocket wheel is provided in place of a tug rim for driving the hoist. Two standard A. P. I. No. 3 drive chains are used. Further information may be obtained from The International Derrick & Equipment Company, who designed and manufacture this rig.



Edited by **BARNEY HORRIGAN**

Why Bring 'at Up?

The Preacher: "I shall speak on 'Married Life' at the morning service, and 'Eternal Punishment' in the evening."

Henpecked (in a whisper): "Sheer repetition."

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The Whole Bunch

"Say, mister," said the little fellow to a next door neighbor, "are you the man who gave my brother a dog last week?"

"Yes."

"Well, ma says to come and take them all back."

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Unforgivable

The Doctor: "And if he loses consciousness again, give him a teaspoonful of that brandy."

The Patient's Wife: "While he's unconscious? Oh, doctor, he'd never forgive me!"—*Texas Ranger.*

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Next Best

Jane: "I want a shorter skirt than the one you showed me."

Clerk: "This is the shortest we have. Have you tried the collar department?"

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Fair and Warmer

"You don't love me as much as you used to. Haven't I always played fair with you?"

"Yeh, you're fair, but I like 'em warmer."

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Yeh, Why?

A young lady entered a stationery store and asked for a pound of floor wax.

"I'm sorry, Miss," replied the clerk. "We sell only sealing wax."

"Don't be silly," she remarked. "Why should anyone want to wax a ceiling?"

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For a Change

Voice from above: "Irene!"

Irene (below): "Yes, mother."

V. F. A.: "The clock has struck '12' three times; now let it practice on 'one' for awhile."

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Low Bridge

She: "Is it dangerous to drive with one hand?"

He: "You bet. More than one fellow has run into a church doing it."—*Cornell Widow.*

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Ailsa: "I suppose you know Alice married money."

Ada: "Oh, yes! They're separated now, aren't they?"

"No; just she and her husband are separated."—*Answers.*

Stupid Things

She: "Don't you think sheep are the most stupid creatures living?"

He (absently): "Yes, my lamb."

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Speaking of Ourselves

Editor (saying grace): "We thank Thee for Thy bountiful blessings, but beg to state that they are unavailable for our present needs."

ƍ ƍ ƍ ƍ

Employer: "What's your name?"
Applicant: "Quinn."
Employer: "Spell it."
Applicant: "C-o-h-e-n."
—*Rutgers Chanticleer.*

WHERE HE IS KING

I am so good for evratheeng
I oughta be electa Keeng!
Ees no som-body else at all
So strong like me, so beeg, so tall,
An' no som-body else can do
So greata theengs lak I can, too.
How mooch you try you no can be
So fina beega man like me.
You bat my life! I oughta gat
A crown for wear eenside my hat,
An' makin' all da style I can
Baycause I am so granda man.
All dees ees true. Eh? how I know?
My leetla boy he tal me so.

You maka fun weeth me an' tease,
An' calls me "Dago" eef you please;
An' mebbe so I what you call
"No good for anything at all."
An' you weel theenk you speaka true
Baycause eet looka so to you.
Wal, mebbe som' time you ees right,
But not wann I gat home at night.
Ha! dat's a time dat I am Keeng
An! I am good for evratheeng!
I know baycause Patricio
My leetla boy, he tal me so.

Do You Know Your Oil Cans?

1. What has a Cat Head to do with a Rat Hole?
2. Has an Oil Thief ever been convicted?
3. Does the work of a Stabber ever cause Bleeding?
4. When does a Wildcat take a Bulldog Fishing?
5. If there is a Blow-out, is it the rock's Fault?
6. Do Collars and Sleeves figure in a toolie's Dressing?
7. Do Rock Hounds have Dog Legs?
8. Can Shoes be pulled up with Boot Jacks?
9. Can a Cheese-box with Crackers yield a square meal?
10. Why isn't a Crown Block all the Headgear needed for drilling?
11. Does a Swivel Neck follow a Rope Choker's operations?

—*The Yellow Strand.*

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Inexperienced

Jim: "Aren't you wild about bathing beauties?"

Jerry: "I don't know; I never bathed one."

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A Gentlemen's Agreement

"Loan me five dollars, will you?"

"Sorry, but I have but four dollars and seventy-five cents."

"Well, give me that. I'll trust you for the other quarter."

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I once knew a man from N. Y.
Who never ate peas with a F.
He ate with his knife
And in fear of his life
Had his implement covered with C.

—*Rutgers Chanticleer.*

ƍ ƍ ƍ ƍ

Doctor: "I hardly like to mention it, but that check you gave me has—er—come back."

Patient: "That's funny, doctor—so have all my symptoms!"

ƍ ƍ ƍ ƍ

Up to Him

"Oh, judge?" cried sad Mrs. Hugglemman. "Must my husband die on the gallows?"

"Of course not, of course not, lady. All we do is tie the rope around his neck and shove him off. From then on its entirely up to him."—*Halliburton Cementer.*

ƍ ƍ ƍ ƍ

Safety First

"Miranda, whassat light shinin' in yo' eyes?"

"That's my stop light, Rastus."

ƍ ƍ ƍ ƍ —*Freedom.*

For 150 years not a shot was heard along the Canadian border, and then someone invented prohibition.—*I. T. I. O. News.*

Write Your Own Ticket

on the

"BJ"

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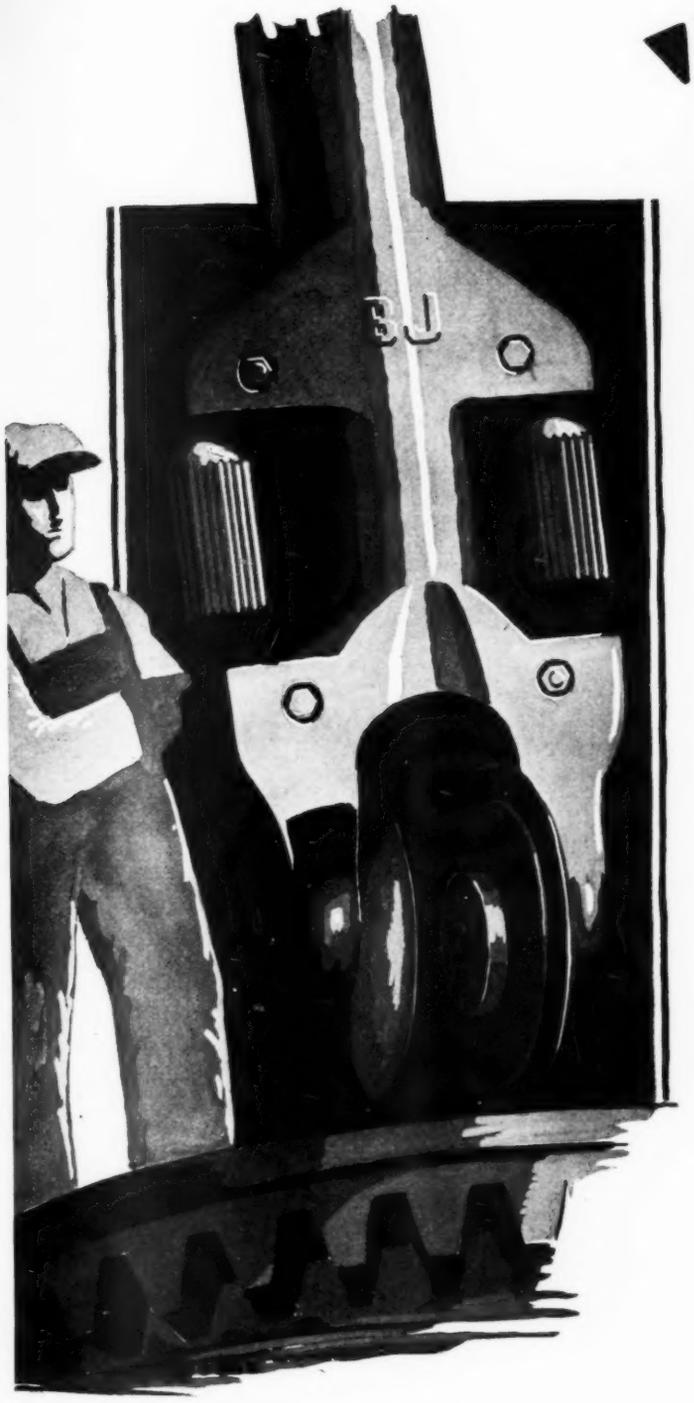

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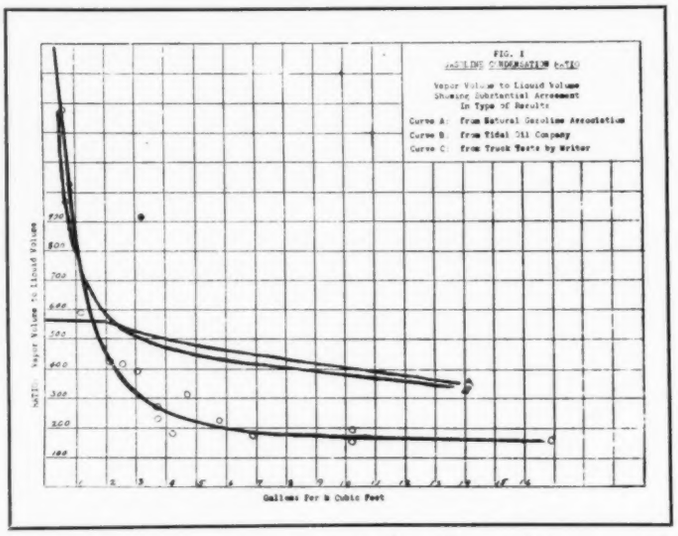
Condensation Effect in Determining Gas-Oil Ratio[1]

By ALEXANDER B. MORRIS [2]

AT THE 1928 meeting, Mr. Morgan Walker, of the Amerada Petroleum Corporation, presented a very complete discussion of the intermittent injection of gas in gas lift operations as opposed to continuous injection.[3] In it he presented a comparative table showing the effect on oil and gas production from the same wells under the two methods of operation.[4] This table carried a column showing the formational gas-oil ratios under each method, computed by deducting the volume of input gas from the volume of trap gas.

During the entire spring and summer of 1928, the writer had been engaged on some extensive test car tests of rich gas in Glenpool, seeking primarily for an explanation of the apparent loss of gasoline between the field meters and the plant master meter during the summer season. Tests at several of the field meters where the richest gas was obtained regularly failed to check with other tests on the same gas made further along the line, and the difference was not made up by the quantity of drip gasoline collected between the points. In the course of these tests, the final outcome of which is immaterial to the present purpose, an attempt was made to construct a curve representing the relationship between gasoline content of the gas in gallons per thousand cubic feet and the shrinkage in the volume of gas treated as a result of removing the condensible fractions. Such a curve was made expressed in units of gallons per thousand cubic feet on the abscissa, and the ratio vapor volume to liquid volume on the ordinate. This curve is a rectangular hyperbola and shows that three gallons of gasoline taken from 1,000 cubic feet of raw gas occupied, as a vapor, very much less space per gallon than did one gallon of gasoline taken from 1,000 cubic feet of another sample of gas. This is, in general, corroborated by converting to the same units the residue settlement curves prepared by the Tidal Oil Company, and by the Natural Gasoline Manufacturers' Association, though the three curves, when plotted together, occupy quite different positions on the paper, as shown in the accompanying plate.


Vapor Volume to Liquid Volume
Showing Substantial Agreement
In Type of Results
Curve A: from Natural Gasoline Association
Curve B: from Tidal Oil Company
Curve C: from Truck Tests by Writer
Gallons Per M Cubic Feet

The bearing of all this on Mr. Walker's discussion of gas lift is this: That if the formational gas-oil ratio is to be computed by deducting the input gas from the trap gas, then some correction must be made for the vapor volume of the gasoline picked up by the dry input gas on its traverse of the system. This may seem at first to be almost negligible, but a little figuring from the production data given by Mr. Walker, using one of these volumetric ratio curves, will show that the corrections are by no means negligible and that they may even be so great as to indicate an actual repressuring of the well, where, by ordinary methods of computation, formational gas was being taken from it. In other words, it is possible that in many instances the vapor volume of the gasoline carried from the well in the trap gas is greater than the difference between the volume of trap gas and the volume of input gas.

Unfortunately the writer has had very little opportunity to pursue these investigations in the field and to carry on prolonged observations of the behavior of wells under varying conditions. Hence, the present discussion is necessarily along academic lines. It was desirable, however, even for this approach to determine a proper starting point or standard of comparison for the gasoline content of the trap gas. Charcoal tests were made at two wells of the Amerada Petroleum Corporation in the Seminole area. Trap pressures were varied and tests made at each of several different pressures with surprisingly regular results. These are shown in Figure 3. As the trap pressure is raised, the gasoline content of the trap gas falls. The parallelism between these curves for these two wells seem to indicate that the gas from each well constitutes a special set of conditions giving rise to a continuous curve for that particular gas. Probably anaylses of these gases, sampled at the different pressures, would disclose the key to this behavior, but no such analyses were made. It is therefore necessary to neglect trap pressures all together in this discussion, but to bear in mind that variations in trap pressure will vary the gasoline content of the trap gas. Let us assume, therefore, that trap pressures are constant under the two methods of production, and proceed to an analysis of some of the data submitted in Mr. Walker's paper. As he did not furnish any figures for the gasoline content of the trap gases corresponding to the other information, it will be necessary also to assume these as well. The values chosen for these contents are as follows:

	G. P. M. Trap Gas
Continuous flow	1.5
Intermittent flow	2.5

Referring to conversion curve B, Figure 2, as being as good a standard as any readily available, it will be seen that the removal of 1.5 gallons of gasoline from gas having that total content results in leaving 80 per cent residue; 2.5 gallons gas leaves 75 per cent residue. In the following calculation, lines A, B, C and E are taken directly from Mr. Walker's data, or in practice, would be supplied by observation:

Line D=C—B.

Line E=D÷A.

Line F is the assumed gasoline content of trap gas. (In practice, actual values should be determined.)

[1] Presented at meeting of Petroleum Division of American Institute of Mining and Metallurgical Engineers, Tulsa, Oklahoma, October, 1929. Subject to author's revision.

[2] Valuation Engineer, Forrest E. Gilmore Company, Tulsa, Oklahoma.

[3] "Intermittent Injection of gas in gas-lift Installations", by Morgan Walker, Petroleum Development and Technology, 1928-29, p. 151.

[4] Ibid, p. 158.

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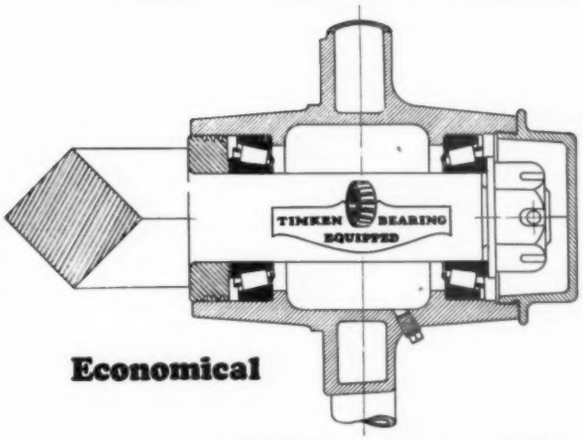

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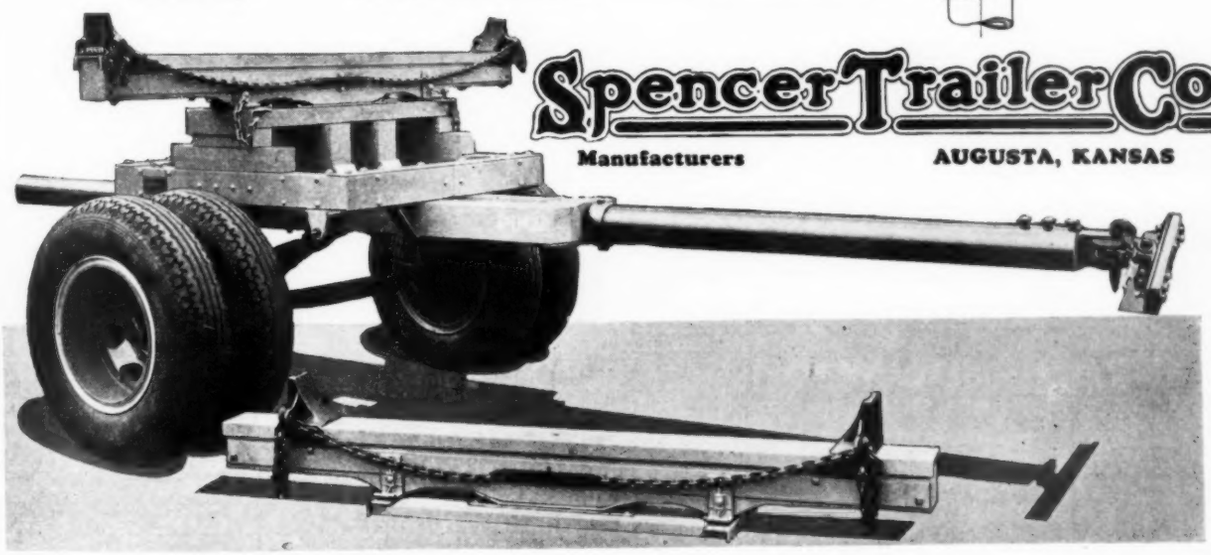

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COMPARISON OF GAS-OIL RATIOS, COMPUTED BY ORDINARY METHOD AND BY METHOD SUGGESTED. BASIC FIGURES TAKEN FROM TABLE I IN MR. WALKER'S PAPER

	Oil, Bbl./Day		Inlet Gas Volume M Cu. Ft./Day		Trap Gas Volume M Cu. Ft./Day		Formational Gas/Oil Ratio Cu. Ft. Gas per Bbl. Oil			
							Apparent		Actual	
	Continuous	Intermittent	Continuous	Intermittent	Continuous	Intermittent	Continuous	Intermittent	Continuous	Intermittent
Anderson No. 2	1,077	1,123	1,516	906	1,762	1,775	228	773	—132	505
Cowden No. 4	1,087	1,124	1,525	1,070	1,750	1,760	207	613	—144	297
Nitey No. 3	986	1,024	1,301	897	1,365	1,135	65	232	—673	—54
Nitey No. 2	914	900	904	767	1,171	1,021	292	282	45	— 3
Nitey No. 4	873	....	1,046	....	1,281	....	269	.....	— 30	....
Fixico No. 3	400	475	1,380	864	1,410	1,652	75	1,660	—787	1,052
Rentie No. 3	508	517	1,014	937	1,275	1,332	514	745	15	14
Killingsworth No. 3	326	290	966	860	1,082	1,130	367	932	—384	—55
Cowden No. 3	279	285	1,111	578	1,220	1,200	391	2,180	—602	1,505

NOTE—Minus signs in Actual Gas/Oil Ratio Column indicate actual repressuring of sand, where, by ordinary method of calculating Gas/Oil Ratio, formational gas is being removed from sand

Line G is the corresponding factor from a conversion curve.

Line H=G×C.

Line J=H—B.

Line K=C—H.

Line L=KX (J÷H).

Line M=KX (B÷H).

Line N=B+M.

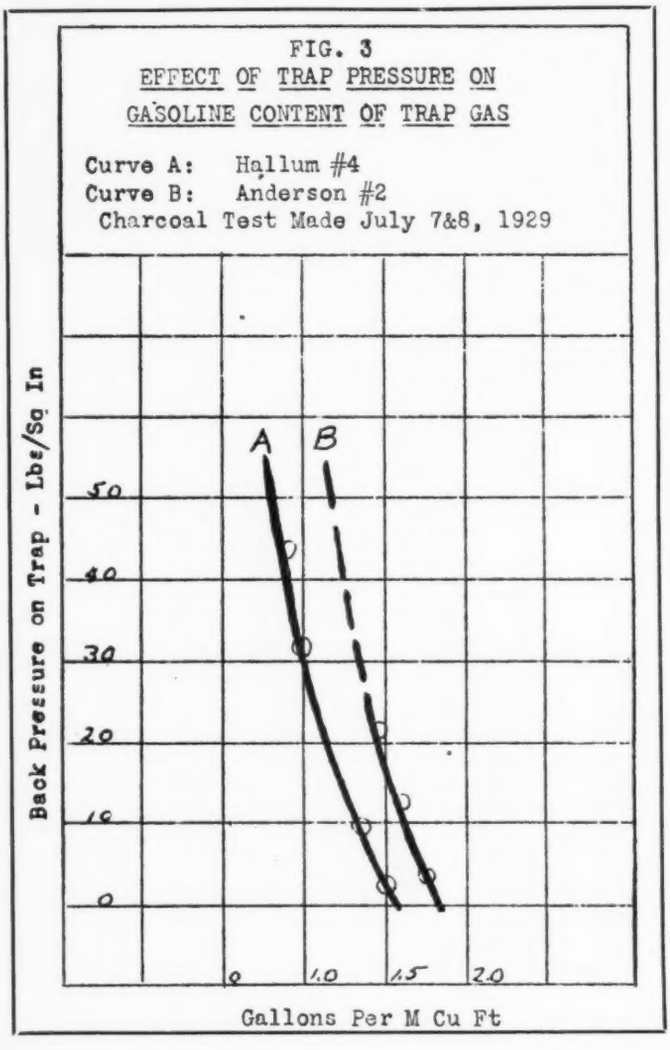
Line P=J+L.

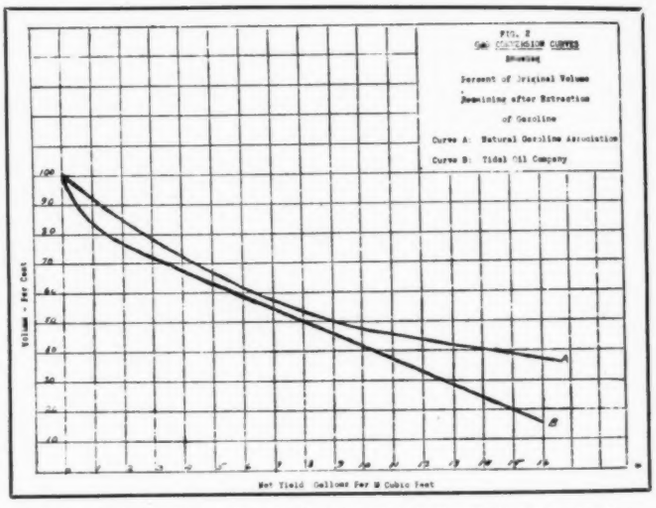
Line R=N+P=C.

Line S=P÷A=(Actual Gas-Oil Ratio).

The figures given in Table 1 are taken direct from Table 1 of Mr. Walker's paper, with the addition of two columns giving the gas-oil ratios computed when condensation affect is considered. The extent of some of these changes is really surprising. For example, Killingsworth 3, under continuous flow, by the ordinary calculation of merely subtracting the input gas from the trap gas, shows that 367 cubic feet of gas is being removed from the sand for every barrel of oil taken out. By the method of calculation suggested herein, 384 cubic feet of gas is actually being returned to the sand for every barrel of oil withdrawn.

It is admitted that many of the factors used in these calculations are open to serious question. No two conversion curves made independently and by different methods can be made to check within 25 per cent or more. The actual observed gasoline content of the trap gases has had to be assumed. The results, therefore, are without quantitative value as applied to the particular wells from which the basic data were obtained. The point of the whole matter is: If gas-oil ratios are to be used as a guide to recovery efficiency production methods, and forecasts as to the life of a field, they should be computed with due regard to all the factors involved of which condensation effect is an extremely important one. Any carefully prepared conversion curve is better than none. Actual gasoline content is easily determined.





TYPE OF COMPUTATION USED TO ARRIVE AT CORRECTED GAS/OIL RATIO.

Line	Anderson No. 2	Continuous Flow		Intermittent Flow
A	Barrels oil	1077		1123
B	Input Gas, Dry, M Cu. Ft.	1516		906
C	Trap Gas, Wet, M Cu. Ft.	1762		1775
D	Apparent Formational Gas	246	(C — B)	869
E	Apparent Formational G/O Ratio	228	(D — A)	773
F	Assumed Gasoline Content of Trap Gas (From Curve B Fig. 2)	1.5		2.5
G	Residue in % of total	80%		75%
H	Dry gas returned to trap	1410	(G × C)	1331
J	Dry Formational Gas	−106	(H — B)	425
K	Gasoline Vapor recovered	352	(C — H)	444
L	Gasoline Vapor carried by New Gas	$352 \times \frac{-106}{1410} = -26$		$444 \times \frac{425}{1331} = 141$
M	Gasoline Vapor carried by Input Gas	$352 \times \frac{1516}{1410} = 378$		$444 \times \frac{906}{1331} = 303$
	Vapor conditions at emergence from trap:	Dry Gas + Gaso. Vapor = Wet Gas		Dry Gas + Gaso. Vapor = Wet Gas
N	Input Gas	1516 + 378 = 1894		906 + 303 = 1209
R	Formational Gas	−106 — 26 = −132		425 + 141 = 566
S	Total Trap Gas	1410 + 352 = 1762		1331 + 444 = 1775
T	Gas/Oil ratio corrected for condensate	$\frac{-132}{1077} = -122.5$		$\frac{566}{1123} = 505$

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Meet Every Need of the Top of the Well From "Drilling in" to Pumping

The above illustration shows 5-3-16" casing being run into the well through McEVOY OIL SAVER which in this instance was screwed into No. 3 McEVOY HEAD. Oil Savers made for Sucker Rods, Tubing and Casing.

NOTE: There is no leakage in the oil saver and it is performing its functions perfectly,—the oil drippings being brought up by the rapid flow of gas through the inside of the pipe being run.

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Repressuring Practice in The Mid-Continent Fields*

By DAVID L. TRAX, *Gypsy Oil Company*
and
T. A. HALL, *Tidal Oil Company*

THE restoration of pressure on depleted oil properties is now passing the experimental stage in the Mid-Continent area, and is recognized as a necessary production method by most operating companies and individuals.

Co-operation in repressuring operations is being carried on quite extensively and satisfactorily where large pools are involved, as it has been recognized that this is one of the essential factors in obtaining successful results. This co-operation is brought about by offset companies using offset pressure wells, introducing the same volumes, and holding the same back pressures. Each company operates their own compressor plant in most cases. However, on many large projects, central plants are installed by companies having large holdings, and compressed air or gas is sold to offset operators at cost. Detail records of repressuring operations are kept by each company, and meetings held at various intervals, and the records compiled in order to show the exact status of the entire project, and to propose any change in operations.

Pressure wells for introduction of repressuring agents are prepared in much the same manner by all companies. In most cases old wells are used and cleaned out by the usual method. The repressuring agent is then introduced through the casing or tubing with a packer set somewhere in, or at the top of the oil sand.

Recently it has been found in the Bradford field of Pennsylvania, where water flooding is practiced, that the method used was very inefficient. By more scientific methods, such as coring and analyzing sand, metering, and introducing water under pressure into saturated portions of sand, they are able to control the water front and obtain recoveries over 40% of the oil in the sand when the flood started. There is no reason why similar conditions cannot be brought about by the use of more scientific methods in repressuring operations.

It is the general opinion that 60% to 80% of the original oil in the sand still remains after normal methods of production have reached the economic limit. If this be the case, the oil industry should make strenuous efforts by research in the devising of ways and means to obtain as much of this remaining oil as practical.

The maintenance of pressure in flush fields has not been carried on extensively in the Mid-Continent area, but replies to the questionnaire indicate that such procedure is theoretically correct, and that pressure of introduction would be the only limiting factor.

The paper, which has been compiled from replies to the questionnaire, should be a subject of general interest, and it is hoped that you will enter into the general discussion for the mutual benefit of all concerned.

This paper has been prepared through the agency of sending a questionnaire to each operator in the Mid-Continent district who has had experience in repressuring. Replies were received from ten companies answering as many questions as they had data upon, or formed conclusions. The answers to each question have been compiled and inserted after each question.

*Presented before the Fall meeting of the Mid-Continent district of the A. P. I. Division of Development and Production Engineering.

Compressor Plants

1. What is the ideal size, in H. P., of units?
   50—100 H. P. (4); 90 H. P. (3)—180 H. P. (3).
2. Do you prefer one central plant for any given property, or several plants of one unit each operated by pumpers? Why?
   Central plants (9); more economical installation, maintenance and operation.
   Several small plants (1); lower labor costs when operated by pumpers.
3. Do you have regular operators on your central plants?
   Yes (7); No (3).
4. Do you prefer gas or oil engines? Why?
   Gas engines (9); more economical installation and maintenance, simplicity of design and operation.
   Oil engines (1); less fuel trouble and saves gas for introduction into sand.
5. Do you prefer 2 or 4 cycle engines? Why?
   4 cycle (10); more efficient and greater fuel economy.
6. Do you prefer semi or full Diesel oil engines? Why?
   Semi (3); simpler, and lower operating costs.
   Full (3); more efficient and economical.
   No experience (4).
7. Do you consider an engine convertible to either gas or oil fuel valuable?
   Yes (9); where air is being used as repressuring medium, or a shortage of gas exists.
8. Do you prefer direct connected or belted units? Why?
   Direct (10); lower installation and maintenance costs, also greater efficiency.
9. To what maximum pressure do you single stage?
   75 pounds (6); 100 pounds (4).
10. What type of intercooler do you use?
    Air cooled coils (5); water cooled coils (3); inclosed water cooled coils (2).
11. What type of aftercooler do you use?
    None used (4); water cooled coils (4); large diameter pipe, air or water cooled (2).
12. Have you standardized on any plant design for repressuring?
    No (7); Yes (3), on new plants.

Surface Equipment

13. What size lateral lines do you use to pressure wells?
    2-inch (8); 2-inch and 1-inch (2).
14. Do you bury the distributing lines?
    Yes (7); No (3).
15. Do you paint the distributing lines?
    No (8); Yes, in some cases (2).
16. Do you use individual separators on producing wells or pump all wells into the receiving tank?
    Receiving tank (10).

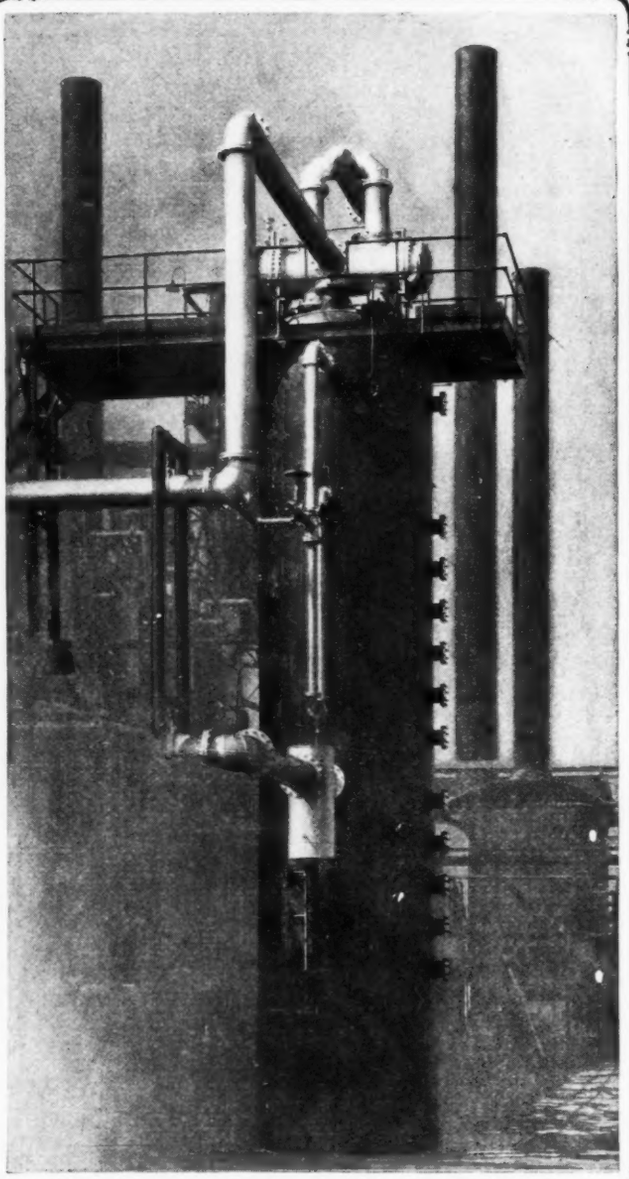
17. Do you install an orifice meter flange on each pressure well?
    Yes (10).
18. Do you install a by-pass around the orifice meter flange?
    No (7); Yes (3).
19. Do you install a permanent recording orifice meter gauge on each pressure well, or take periodical readings with a portable gauge?
    Permanent meters (6); periodical readings (4).
20. Do you use manual control or automatic volume controllers for regulating the volume to each pressure well?
    Manual control (10).
21. Do you install a check valve on each pressure well?
    Yes (6); No (4).

Selection of Pressure Wells

22. Do you use the name pressure, key, air, intake, or injection, to designate the well used to deliver the pressure medium to the sand?
    Pressure (8); Key (2).
23. Do you determine porosity and saturation of a sand before making permanent installation in any pool? If so, how is sample obtained?
    No (10). Although all answered negatively, three favored such a procedure.
24. Do you locate your pressure wells by sub-surface study, or geographically?
    Geographically (5); both (5).
25. Do you locate your pressure wells so that the drive will be up structure, or down structure? Why?
    Up structure (6); in most cases there is a tendency for repressuring medium to travel up structure.
    Down structure (1).
    Disregard (3); other factors more important.
26. Do you think all pressure wells should be newly drilled wells for that purpose? Why?
    No (7); uneconomical.
    Yes (3); old wells have been inaccurately logged, and it is difficult to obtain an efficient drive.
27. Do you place much value on sand thickness, initial production, present production and rate of decline, in making selection of pressure wells? Why?
    Yes (10); thicker sand provides greater outlet area, initial production and rate of decline indicate porosity or loose sand, so that greater results may be obtained at low pressure. Present production considered from economic standpoint.
28. Do you try to avoid selecting wells which are producing water? Why?
    Yes (10); a higher pressure is required to force water into sand and may also cause flooding or a water drive, if excessive.
29. Do you think a drilled pressure well should be cored? Why?
    Yes (10); in order to obtain information relative to sand porosity and saturation. Also, to determine proper casing point or preparation of pressure well.
30. Do you think a drilled pressure well should be shot? Why?
    Yes (6); if sand tight and hard shooting provides greater area for introduction of medium and better distribution.
    No (4); shooting has a tendency to create channelling.
31. Do you consider that a well which has been responsive to vacuum will make a good pressure well?
    Yes (10); vacuum creates a differential in pressure the same as repressuring, except that by repressuring a greater differential is obtained, therefore greater results.
32. Do you consider that a property or pool which has been responsive to vacuum will result in a successful repressuring proposition?
    Yes (10); if by-passing can be prevented.
33. Do you make preliminary tests to determine pressures and volumes required for a property?
    Yes (7). No (3).
34. What sort of compressor installation do you make for preliminary test?
    Portable two stage Compressing Unit (9).
    Small compressor belted to powers (1).
35. In the selection of pressure wells do you select the largest or smallest producing wells? Why?
    Smallest producers (6); less loss of production during time repressuring is becoming effective.
    Large producer (2); it has been found that good producers make the best pressure wells from standpoint of efficiency and recovery.
    Disregard present production (2).
36. Do you consider sand of high gravity oil more favorable to repressuring than one of low gravity?
    Yes (6); quicker and more profitable results are obtained.
    No (4); there is no difference in results obtained.

Preparation of Pressure Well

37. What methods do you use in preparing the pressure well to insure the repressuring medium being introduced into the oil bearing part of the formation?
    On old wells, casing is underreamed and cemented on top of sand, or at break in sand. Tubing and anchor packer set at break in sand, tubing and shot hole packer set at top of shot hole, tubing and rag packer cemented at top of sand or at break in sand. On new wells, casing is cemented, or set on top, or at break in sand.
38. Is pressure well equipped so that tubing and rods may be run, and the well put back to pumping?
    Yes (10).
39. When old wells are used as pressure wells, should they be properly cleaned out and shot?
    Yes (10); if hole is filled with mud to top of sand, or if sand is paraffined.
40. What percentage of pressure wells have you put back to producing on account of unsatisfactory service for pressure?
    5% (2); 2% (2); very few (5); none (1).
41. Do you practice changing pressure wells periodically to get cross-drives?
    No (7); but believe it is good practice in soft porous sands.
    Yes (3).
42. From what operating data do you determine the proper input volume after the whole pool is equipped and operating?
    In most cases the proper input volume is determined by performance of the surrounding producing wells, that is, the increase of gas or oil from these wells, tendency to channel, etc.
43. How often do you determine pressure well volumes if you do not have a permanent recording meter on same?
    Monthly (1); Semi-monthly (2); Weekly (3); Depends on property (2).
44. What methods have you used for controlling by-passing through the oil pay? List in order of best results.
    Stop-cocking or holding gas back-pressure, was listed as first by (5); and increasing the fluid level to hold fluid back-pressure by raising tubing or



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changing stroke on well, was listed as first by (5). Other methods listed were, reducing input volumes, changing pressure wells, and combination gas and fluid back-pressures.

45. What methods have been successful in preventing by-passing through a top gas sand where there is no break between it and the oil pay?

Only three (3) companies reported on this question. They suggested close spacing of pressure wells with respect to producing wells, or carrying gas or fluid back-pressures on all wells.

46. What are relative values for pressure medium, (1) air; (2) dry gas; (3) wet gas; (4) stabilizer vapors; (5) exhaust gases; (6) hot gas; and (7) hot air as affecting, (1) volume required; (2) efficiency as propelling medium; (3) gravity of oil; (4) corrosion; (5) gasoline content of casing head gas; and (6) emulsions?

(1) Air—less volume, lower efficiency, little raise in gravity, increase in corrosion, decrease in gasoline content, more emulsions.

(2) Dry gas—more volume, high efficiency, increase in gravity, no corrosion, slight increase in gasoline content, no emulsions.

(3) Wet gas—less volume, not so efficient, raise in gravity, no corrosion, increase in gasoline content, no emulsions.

(4) Stabilizer vapors—same as wet gas.

(5) Exhaust gases—highly corrosive, therefore condemned.

(6) Hot gas—same as dry gas, possibly more efficient as expelling agent.

(7) Hot air—no advantage over cold air.

47. What have you done to overcome corrosion of pumping equipment?

Alloy and plated equipment used (5).

Chemical introduced into casing of pumping well (1).

No excessive corrosion present (4).

48. What safety measures have you taken to prevent explosions when compressing air?

Proper kind and minimum amounts of lubricating oil, soap lubricant, install drips on high pressure discharge, use large relief valves, keep compressor valves in good condition, use arresters and automatic temperature shut down device, have safety rules and use judgment in operation.

49. What safety measures have you taken to prevent explosions when compressing a mixture of air and gas?

Do not compress mixture of air and gas under any circumstances (3).

Make frequent analyses of mixture to determine percentage of air (4).

Use same safety measures as above (3).

50. What minimum percentage of gas do you consider safe to compress with air to 300 pounds pressure?

None (3); as percentage may change at any time due to leakage and cause explosion.

40% (3); 25% (1); 60% (1); no experience (2)

51. How do you measure the casing head gas volumes?

Orifice Well Tester (5).

Recording meters (2).

Positive meters (1).

Orifice Well Tester on some wells, recording meters on others (2).

52. How often do you measure casing head gas volumes?

Monthly (4); Semi-monthly (1); Weekly (1); Daily (2); Every 2 to 3 months (2).

53. Do you use an analyzer for determining the air content of the gas, and do you attach much importance to the data?

Yes (8); it shows rate and direction of distribution, also determines by-passing.

No (2).

54. Do you find your corrosion trouble increases as the CO_2 percentage increases?

Yes (5); No (1); No experience (4).

55. What is your theory as to the formation of the CO_2?

Oxygen combines with hydrocarbons to form water and carbon dioxide (2).

Catalytic action (1).

No theory (7).

56. What do you do with gasoline condensed in after-cooler and lines?

It is drained into drums and hauled to gasoline plant, or used in tractors and automobiles. It is also dumped into casing of producing wells, or forced into sand through pressure wells.

57. How do you make individual oil and water tests?

Permanent test tanks (5).

Portable test tanks (3).

Gauge in flow tank (1).

Estimate from pumping time (1).

58. How often do you make these tests?

Monthly (4); Quarterly (1); Semi-annually (1); Weekly (3); Semi-monthly (1).

59. If you are not producing your wells to capacity, do you periodically make maximum tests, and how often?

Produce to capacity (9).

Periodical tests made once a month (1).

60. Do you find that your pulling increases from the application of air?

Yes (5); No (2); In some cases (3).

61. Do you find that your operation and maintenance increases sharply with application of pressure and then gradually reduces?

Yes, in most cases (6), probably due to increased activities on properties.

No (4).

62. When a vacuum property is repressured, do you eliminate the vacuum entirely at any specified time, continue the vacuum, or gradually reduce the vacuum as the drive becomes effective?

Gradually reduce (7); in order to prevent loss of gas and oil production.

Eliminate at once (3); in order to prevent channelling and obtain quicker results.

63. Do you shut down all producing wells until drive has had an effect, or do you try to get all the production you can from the beginning?

Produce all we can from beginning (9).

Control production according to distribution of pressure medium (1).

64. Do you try to increase production rapidly from the beginning, or do you start with volumes even less than preliminary tests show and gradually increase as you note the effect?

Increase production slowly, using small volumes and gradually increasing (10).

65. What do you do with water or oil in a pressure well before turning in pressure?

Force into sand (7). Bail, swab or flow out (3).

66. In what order do you notice increases in water, oil and gas?

Gas, oil, water (7); Water, gas, oil (1); Gas, water, oil (1); Oil, gas, water (1).

67. What various operating agreements do you have with offset operators?

In most cases co-operation is practiced, using offset pressure wells and introduce same volume into each well, holding same back-pressures on producing wells. Drill new wells on line and pro-rate expenses. Buy and sell compressed air or gas for introduction on offset properties.

68. How close to your property line do you locate pressure wells if the offset operator does not join in repressuring?

Two locations (9); unless high part of structure on property, if so, locate pressure well on line.

One location (1).

69. Have you had any success in preventing migration of oil from your lease by pulling vaccum on line wells offset by wells on which vacuum is maintained?

Yes, in some cases (7); No (3).

70. What other methods other than pumping are you using to operate the producing wells?

None (6). Automatic flowing (4).

71. Considering depreciation, operation and maintenance on plant and lines, what is your compressing cost per 1000 cubic feet, at 100 pounds, 200 pounds, 300 pounds and 400 pounds?

100 pounds— .03 to .045.
200 pounds— .04 to .05.
300 pounds— .06 to .065.
400 pounds— .07 to .08.

72. Will repressuring retard water encroachment?

Yes (9). In some cases (1).

73. Have you shut down all producing wells and continued to operate the plant, for any length of time, in an effort to build up the rock pressure? For how long, and what were the results?

No (5).

Yes (2); three months, no results.

Yes (3); three months' slight temporary increase. Results depend largely on condition of sand and property, also structural conditions.

74. What has been your experience in repressuring during early stages of development?

No experience (6).

Good results semi-flush production (1).

Good results in one case during early stage (3); reduces rate of decline.

75. Do you believe that, theoretically, this is the time to start repressuring? Why?

Yes (9); gas is usually available, tends to retard water encroachment and lowers gas to oil ratio. Conservation of gas.

No (1); natural energy within sand should be partially utilized before artificial means are undertaken.

76. Do you believe that it is practical to do so? What would be the limiting factor?

Yes (9); unless pressure for introduction extremely high.

Compression costs, availability of gas and pressure of introduction limiting factors.

No (1); best results obtained from settled production.

77. What is your opinion of percentage of unrecoverable oil by normal methods before repressuring is applied?

60% to 80% (6); depending on type of sand.

No experience (3).

Bartlesville Sand 70%-85%; Wilcox Sand 40%-70%.

Lime 30%-60% (1).

78. Tabulated Data on Properties.

So few answered this in detail, and the projects in some formations are so few, tabulation is made only on projects where a sufficient number are included to give representative values.

Projects reported, by sands, are as follows:

Sand	Projects	Operation	Abandoned
Bartlesville	21	19	2
Peru	3	3	0
Strays	7	7	0
Glenn	3	2	1
Squirrel	2	2	0
Perryman	1	1	0
Upper Hoover	1	1	0
Cromwell	4	3	1
Burbank	3	1	2
Taneha	1	0	1
Tonkawa	1	1	0
Shawver	1	0	1
Totals	48	40	8

Tabulated data, submitted as representative averages, follows:

	BARTL'E. 0-1000'	BARTL'E. 1000-2000'	BARTL'E. over 2000'	STRAYS 0-1000'	SQUIRREL Varies
1. Formation					
2. Projects included in data	7	7	4	6	2
3. Age at Repressuring:					
a. Minimum	6 Years	7 Years	3 Years	1 Year	13 Years
b. Maximum	22 Years	21 Years	16 Years	10 Years	15 Years
c. Average	14 Years	13 Years	8 Years	6 Years	14 Years
4. Age of Repressuring:					
a. Minimum	2 Years	1 Year	1 Year	1 Year	1 Year
b. Maximum	5 Years	4 Years	1 Year	3 Years	3 Years
c. Average	3 Years	3 Years	1 Year	2½ Years	2 Years
5. Average Sand Thickness:					
a. Minimum	18′	20′	35′	12′	20′
b. Maximum	39′	70′	77′	35′	25′
c. Average	28′	45′	56′	23.5′	23′
6. First Production Increase (Time):					
a. Minimum	30 Days	30 Days	120 Days	12 Days	30 Days
b. Maximum	180 Days	90 Days	.....	90 Days	90 Days
c. Average	70 Days	60 Days	.....	40 Days	60 Days
7. % Production Increase (At Max.):					
a. Minimum	115	13	0	52	398
b. Maximum	473	238	95	246	900
c. Average	210	85	.....	102	523
8. % Production Increase (At Present):					
a. Minimum	80	0	0	26	163
b. Maximum	359	135	95	100	900
c. Average	146	27	0	91	347
9. Change in Gravity:					
a. Minimum	0	0	0	0	0
b. Maximum	Minus 1	Plus and Minus 1	Plus 1	Minus 2	Minus 1
10. Producing Wells:	1320	438	86	888	16
11. Pressure Well Ratio:					
a. Minimum	6.84	15.0	13.0	9.0	4.0
b. Maximum	5.38	3.5	6.3	4.8	4.0
c. Average	6.3	8.5	9.4	8.1	4.0
12. Pressure:					
a. Minimum	75	45	75	100	100
b. Maximum	240	350	250	200	260
c. Average	125	170	150	145	180
13. Project Cost per Well:					
a. Minimum	$129.00	$157.00	.....	$192.00	.....
b. Maximum	522.00	943.00	.....	640.00	.....
c. Average	252.00	445.00	.....	277.00	.....
14. Project Cost per H. P.:					
a. Minimum	$150.00	$123.00	.....	$100.00	.....
b. Maximum	476.00	305.00	.....	244.00	.....
c. Average	187.00	232.00	.....	212.00	.....
15. H. P. per Well (All Wells):					
a. Minimum	0.5	0.8	.....	1.7	.....
b. Maximum	3.3	6.5	.....	3.8	.....
c. Average	1.4	2.5	.....	2.3	.....
16. Lifting Cost Change (Present):					
a. Maximum increase	25.0%	87.5%	.....	100.0%	.....
b. Maximum decrease	34.6%	40.6%	.....	43.0%	.....
17. Input Volume per Well:					
a. Minimum	10,000	25,000	70,000	26,000	25,000
b. Maximum	85,000	90,000	250,000	60,000	50,000
c. Average	18,000	41,000	161,000	33,000	31,000

NOTE—All averages are the true mathematical averages, and not project averages.

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Electric Welding of Field Joints of OIL *and* GAS PIPE LINES†

By HAROLD C. PRICE*
Bartlesville, Okla.

PRIOR to September 1, 1928, there had never been constructed what might be termed a long pipe line with electric-welded field joints. Nevertheless, by September 1, 1929, within the period of a year, more than 2500 miles of electric-welded lines have been completed. These lines vary in diameter from 6 to 20 in., and in length from 50 to 700 miles. Before September 1, 1928, no such line had been constructed longer than 50 miles, and only one of nearly that length—a 40-mile 7-in. gas line in Louisiana. This was in reality the first pipe line to use electric-welded field joints. During the past year the following lines have been electric-welded by the Welding Engineering Co. alone:

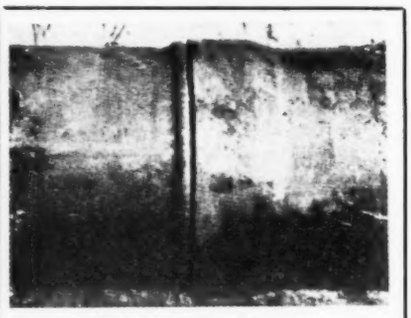

Fig. 1. Bell and spigot pipe with welding dam.

Texas Pipe Line Co.—157 miles of 8-in. line from Corsicana, Texas, to San Augustine, Texas. (This was the first electric-welded oil line.)

Texas Pipe Line Co.—80 miles of 8-in. from Lafors, Texas, to Childress, Texas.

Texas Pipe Line Co.—39 miles of 10-in. from Monahans, Texas, to Jal, New Mexico.

Texas Pipe Line Co. — 50 miles of 6-in. from San Antonio, Texas, to San Marcos, Texas. Texas - Empire Pipe Line Co.—424 miles of 12-in. from Cushing, Okla., to Chicago, Illinois.

In addition to the field welding mentioned above,[1] 250 miles of 12-in. line was electric-welded into double joints at the pipe mill at Indiana Harbor, Ind.

Equipment

Pipe—All of the pipe welded was equipped with the bell and spigot joint. About 70 per cent of the joints on the 8-inch line were equipped, in addition, with a welding dam on the spigot end (Fig. 1). Most of the pipe was electric welded, with a carbon content of 0.20 to 0.30; the remainder of the pipe was lap-welded, with a carbon content of 0.06.

Welding Machines—It was decided to use 300-amp. generators on the firing line, or rolling welds, and 200-amp. generators on the bell-hole, or tie-in welds. Power for the large generators was furnished by six-cylinder motors, and for the smaller generators by four-cylinder motors. The six-cylinders operated at 1,500 r.p.m., and the four-cylinders at 1,200 r.p.m. A 300-amp. unit, with a four-cylinder motor running at 1,500 r.p.m., could have been obtained, but previous experience on welding tank roofs had taught us that constant use of a four-cylinder motor running over 1,200 r.p.m. necessitated an unusual amount of repair. The fact that the engines would have to operate the welding machines at least 10 hours per day under nearly constant load was taken into account.

Welding Wire and Accessories—The welding wire was a mild-steel, loosely coated rod. The welding leads consisted of 200 feet of 00 rubber-covered cable. The other accessories were of the usual type.

Fig. 2. Caterpillar tractor moving welding machine along right of way.

Transportation—The problem of transporting the machines along the right of way was of great importance. The larger machines weighed nearly 3,000 pounds. On the first line constructed, each machine was placed on a wagon and drawn by a team, but on subsequent lines it was found that three teams could handle upwards to eight machines on the firing line. Eventually even these were dispensed with and a 2-ton caterpillar tractor was substituted, capable of moving as many as 11 machines throughout the day (Fig. 2). On the tie-in gang, however, it has been found advantageous to have a team for each one of the units.

The most efficient method of furnishing gasoline to the engine was to place a 55-gallon gasoline barrel on the same

† Presented before the Fall Meeting of the A. I. M. E. at Tulsa, Okla.
* General Manager, Welding Engineering Co.
1 The electric welding data contained in this paper were collected solely from the pipe lines mentioned.

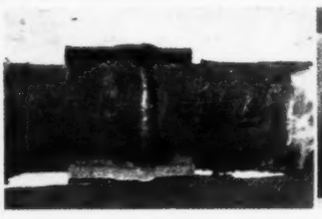

Fig. 13. Reinforcing straps welded on 8-in. pipe for river crossing in Texas Panhandle.

Fig. 14. Reinforcing straps welded on 12-in. pipe crossing Arkansas River.

Fig. 17. River clamps to be bolted over welded joints on large river crossings.

Fig. 18. River clamp bolted to pipe on Arkansas River crossing.

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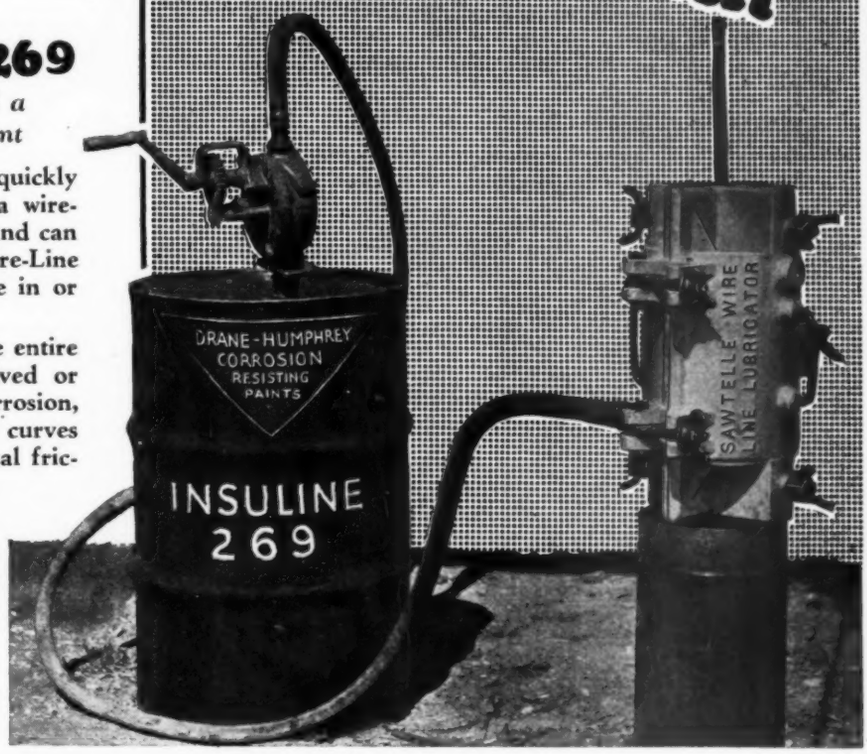

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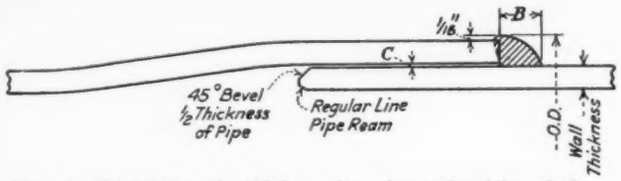

Fig. 19. Dimensions of weld for various sizes and weights of pipe.

wagon with the machine and run a tube direct from this barrel to the vacuum tank. This caused the minimum amount of refueling.

Operation

Organization—In constructing a long pipe line, the work is usually divided and assigned to two or more complete gangs, depending on the length of the line, and each gang completes its proportionate amount of welding. Each gang is in charge of a welding foreman and is divided into two units, the firing-line unit and the bell-hole unit. The firing-line unit consists of from 6 to 12 welders, depending on the amount of pipe to be lined up and welded per day. Each welder has a helper, who chips or scales the weld and turns

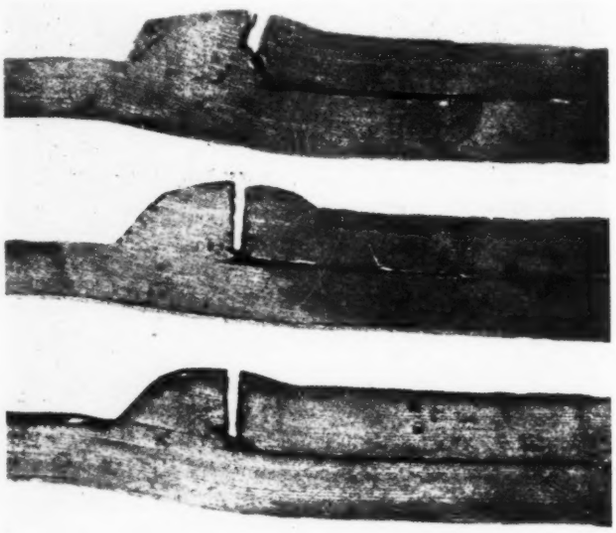

Fig. 22. Cross-section of coupons cut from welded joint for tests of tensile strength, parts reassembled after being broken.

the pipe, as explained later. For each gang there is a mechanic and a tractor driver, one of whom acts as a truck driver when necessary.

General Procedure—The pipe is first lined up along the right of way on skids in sections averaging about six lengths each. Thus, if the pipe were delivered in 40-foot lengths, each section would average 240 feet, in which there would be five joints to be welded. These joints are all welded from the top by turning or rolling the pipe on the skids. Each welder is assigned to a section, and he completes all welds in that section before moving ahead. Following the firing-line welders come the bell-hole welders, usually two or three, depending on the nature of the country and the speed with which the pipe is being put into the ditch. The pipe-line crew connects the previously welded sections over the ditch, placing them upon skids. When the sections are connected, the bell-hole welders make the final weld. It is obvious that the pipe line cannot be turned as it is now in one continuous tube, therefore the bell-hole welders must weld completely around the pipe while the pipe remains stationary. Naturally only the best welders are put on the tie-in work.

Method of Welding—The pipe ends are first cleaned of rust, dirt and grease by using gasoline or kerosene and a wire brush. When the pipe is delivered with a protective coating, this coating or tar often gets on the ends of the pipe, and it is sometimes necessary to remove it either by scraping or burning it with a torch. The electric weld is applied in two beads. With the pipe lined up on skids, the welder welds the upper half of the first bead. He does this on each joint in the section successively. During this time the pipe is not being turned. This half also serves as a tack weld and keeps the pipe in line for subsequent operations. After the upper halves of the first beads are completed, the entire section is turned 180 degrees and the other half of the first bead is welded on each joint.

Fig. 23. Welding near Hannibal, Mo., in mid-winter. Note improvised heater directly behind welder.

Each bead is covered by a certain amount of hard scale, which must be chipped off before the second or final bead is applied. The helper, therefore, follows the welder after each bead and chips off this scale with a hammer and chisel. This in no way delays the welder, as he is welding a new joint while the helper is scaling the old one.

After all the first beads are scaled, the section is ready for the second or finishing weld. For this weld the pipe must be turned continuously. This is done by the helper with the usual chain tongs. The welding on the finishing weld is done on the top of the pipe only. After each weld is finished, the welder will peen the final junction with his hammer, move on to the next joint and again make a com-

Fig. 24. Sample of spring mud in Missouri. Caterpillar of line-up machine completely submerged.

Fig. 25. Pulling welding machine through heavy mud

plete weld, and so on until the whole section is completed. The finishing weld is not scaled.

Procedure on the bell-hole weld is slightly different, for, as mentioned above, the pipe cannot be rolled. A hole in which he will have room to operate must be dug for the welder in the ditch beneath the pipe. He starts the first bead at the bottom of the pipe and welds up one side to the top. He repeats on the other side of the pipe until the entire first bead is finished. After this bead is scaled, he puts on the second bead in the same manner. Where the pipe-line crew is making good speed in tying in the sections, one welder will be assigned to putting on the first bead only, thus tying in the pipe quickly and delaying the pipe-line crew the minimum amount of time while the weld is being made. Sometimes it is necessary to use three tie-in welders. In this case one is used for tack-welding the joint as it is lined up by the pipe-line crew and the other two finish the weld. It is evident that each tie-in weld must be welded substantially before the pipe-line crew can add another section, particularly if there are any bends to be made in the line.

Welding River Crossings—Extra heavy pipe was used on the large river crossings and a proportionally heavy weld was applied. River straps of two different designs were welded across the weld (Figs. 13 and 14). On the small rivers the pipe was welded in sections on shore and pulled across, being tied in to the line on the banks. On the larger rivers, such as the Mississippi and the Missouri, the pipe was welded on the barge and lowered into the river after the welding of each joint. Heavy river clamps were bolted over the weld before lowering.

Welding Current and Welding Wire—On the firing line $\frac{3}{16}$-inch welding rod is used for the first bead, with a current of 175 amp. For the second bead $\frac{7}{32}$-inch or ¼-inch wire is used, with a current of from 200 to 250 amp. For the bell-hole weld, $\frac{3}{16}$-inch wire is used for both beads.

Gasoline and Oil Consumption—The six-cylinder machines consume about 2 gallons of gasoline per hour, and the four-cylinder machines 1½ gallons per hour. The average amount of lubricating oil used on all machines is 0.8 gallons per day.

Specifications

The specifications called for a uniform weld of good appearance; the outside diameter of the weld to be approximately ⅛ inch greater than the outside diameter of the pipe bell, and the top of the weld not to be lower than the top of the bell at any point on the circumference. A sketch of the cross-section of the weld as applied to the pipe joint is shown in Fig. 19, together with a table of dimensions for various sizes of pipe.

Pipe Outside Diameter, Inches	Weight Per Foot, Pounds	Wall Thickness, Inches	*B* Inches	*C* Inches
6⅝	17.021	0.250	0.500	0.031
8⅝				
10¾				
12¾	40.000	0.303	0.500	0.047
12¾	65.415	0.415	0.520	0.040

Inspection

All welding is done under rigid inspection by the pipe-line owners and also by the welding contractors. There is an inspector on both the firing line and the tie-in gangs. Each weld is supposed to be inspected as it is made. Coupons are cut periodically with a milling machine from welds completed by each welder. These coupons are merely slices of the welded joint. They are about ¼ inch thick, and cannot be used for strength tests. However, they do show a cross-section of the weld, and an indication of its size and penetration. Complete welds are also cut out at various times, and from these tests of tensile strength are made. Any welds that do not measure up to proper specifications are immediately marked and rewelded. Where the bell and spigot joint is cut out for any reason, it is replaced by a split sleeve. The pipe is first welded with an ordinary butt weld; the sleeve is then slipped over this weld, and the split of the sleeve is welded. Both ends of the sleeve are then welded to the pipe.

Results of Tests

Tensile Strength—Table 1 gives the results of tests of tensile strength made from coupons cut from 52 welds on the 12-inch line from Cushing to Chicago. The strength of these coupons averaged 50,870 pounds per square inch. Practically all broke through the weld near junction with the bell, as shown in Fig. 22, which shows the cross-section of three coupons, with the pieces replaced after they were broken. They tested as follows: 67,500 lbs. per sq. in.; 57,000 lbs. per sq. in.; 53,900 lbs. per sq. in. Only a few of the coupons broke in the weld near the spigot.

Tables 2 and 3 show the results of tensile tests made by pulling entire lengths of 12¾-inch pipe, each including a completed field joint. The sections noted in Table 2 were all cut out of the Cushing-Chicago line. All of these sections broke in the joint except No. 10, which broke 2 feet from the weld. The other nine were broken in the weld, or adjacent to it. The sections noted in Table 3 were taken from pipe welded into double lengths at the mill. Section 1 broke in the pipe and the other two sections in the weld.

Hydraulic—Hydraulic tests were made on all the lines as quickly as sections were completed and pumping arrangements could be made, using from 800 to 1,000-pound water pressure. Over 140,000 welds were made on the lines referred to, and the number of leaks discovered was practically negligible. Only two small leaks were found on the San Augustine-Corsicana line; about a dozen were repaired on the Lafors-Childress line; not a leak was discovered on the 40 miles from Monahans to Jal or on the 50 miles from San Antonio to San Marcus. On the 354 miles of the Cushing-Chicago line tested at the time this is written, only three leaks have been found, all of these being within a 23 mile section. All of the leaks mentioned were small pinhole leaks that were readily repaired.

Time and Speed of Welding Operations

The cost of the welding is determined by the number of welds that can be made by a welder per day. Where welding is done in a shop, this can be readily determined, but pipe lines cannot be laid in a shop and must be put down in all kinds of country and under all kinds of weather conditions. We will take the various jobs mentioned in the order in which they were built.

The San Augustine-Corsicana line was laid during the fall of 1928 in extremely rough country. The weather conditions were excellent until the last two weeks of operation. Under these conditions all welders, including both bell-hole and firing-line welders, averaged 15.3 welds per day. In computing the average number of welds made, bell-hole welders should not be taken into consideration, because in tying in pipe there are so many delays possible for which the welding is in no way to blame. The real speed of the welding can be determined by computing what the firing-line

welders are doing. On this 8-inch line, the firing-line welders averaged 21 welds per day.

The 10-inch line from Monahans to Jal was laid in level country, and during fairly clear weather. The greatest delays were caused by severe sandstorms, which made work impossible for about 30 per cent of the time during the last two weeks. The average speed of the firing-line welders on this line was 19.9 welds per day.

On the San Antonio-San Marcus line, with the exception of 15 miles, the country was fairly level, but the weather was extremely wet, which caused considerable loss of time and reduced the average number of welds below that of the two former lines. The average per man was 17.7 per day on the firing line.

The Cushing-Chicago line ran through both level and hilly country. Work started February 1, 1929, when the ground was frozen (Fig. 23). Spring thaws started early in March, so that it was necessary to move machines through 15 inches of mud when possible (Figs. 24 and 25). Following the thaw, the heavy and continuous rains arrived, and it was not until June 15, and in some places even later, that it was possible to weld pipe on dry ground. The welding speed on the 12-inch pipe for the firing line from start to finish averaged 10.3 welds per man per day. When good weather arrived, the average rose to 13 welds per day.

As to the actual time of making a complete weld on 12-inch pipe, 0.303 inches thick, the average for the rolling welds has been found to be 30 minutes and the bell-hole welds 45 minutes. The time for electric welding of other sizes of pipe of the same thickness has been in direct proportion to the diameter.

Throughout the welding of these lines, there have always been certain times when conditions were ideal, when some welder would set an extremely high record for one day. The maximum number of welds per 10-hour day for one man has been: 6-inch, 38 welds; 8-inch, 40 welds; 10-inch, 28 welds; 12-inch, 25 welds.

TABLE 1.—*Tests on Tensile Strength of Coupons Cut from Electric-welded Field Joints.*

Pipe Size, O. D., 12.75 Inches; Wall Thickness, 0.303 Inches; Wt. Per Ft., 40 Lbs.; Carbon Content, 0.20 to 0.30.

Amperage	Tensile Strength, Lbs. Per Sq. In.	Amperage	Tensile Strength, Lbs. Per Sq. In.
200	48,000	180	48,800
190	48,750	200	51,200
200	50,875	200	48,830
190	49,700	200	51,750
200	66,560	180	53,850
150	46,500	180	48,600
200	53,500	178	55,800
175	40,760	200	53,200
170	47,730	200	47,950
200	54,200	180	53,300
180	52,025		

Average tensile strength 31 additional tests. Amperage not available, 47,276. Average amperage, 188. Average tensile strength, 50,870 pounds.

Comparative Costs

As mentioned, it is difficult to give reliable costs for welding various sizes of pipe, either by the electric or any other method, as the costs depend on the speed of the welding, and the speed depends on the nature of the country and the condition of the weather. Because of this feature, it would be misleading to compare the costs of electric welding with those of gas welding unless two pipe lines of the same kind of pipe were laid in the same locality at the same time, and even then, for accurate comparison, the cost-keeping system would have to include identical items. The company with which the writer is connected has never attempted to weld pipe lines by the acetylene method, and the figures given to us by various contracting companies have varied to such a great extent that we have been unable to use them. However, one of the largest oil companies, a pioneer in the gas-welding of pipe lines, has keen kind enough to compare its costs with ours on a parallel basis. We divided the costs into four items as follows:

1. Labor, as applied to each welder. This included, for gas welding, the welder, helper and teamster, and for electric welding, the welder, helper, mechanic and tractor driver.

2. Generation, including for the gas welders, acetylene and oxygen, and the cost of transportation of these, with containers, to and from the job; for electric welding, gasoline and oil.

3. Welding wire.

4. Depreciation.

TABLE 2.—*Tests on Tensile Strength of Electric-welded Pipe Joints (Entire Joint Pulled on Testing Machine).*

Pipe Size, O. D., 12.75 In.; Wall Thickness, 0.303 In.; Carbon Content, 0.20 to 0.30. Open-hearth Steel.

Test Number	Tensile Strength, Tons: Pipe	Tensile Strength, Tons: Welded Joint	Efficiency of Welded Joint Per Cent
1	386.05	310	80.30
2	431.86	325	75.95
3	419.21	278	66.31
4	346.98	278	80.12
5	349.74	318	90.92
6	366.05	320	87.42
7	441.58	285	64.54
8	413.21	252	60.97
9	498.07	275	64.24
10	342.88	324	94.49
Average.....	392.57	296.50	75.52

TABLE 3.—*Tests on Tensile Strength of Electric-welded Pipe Joints (Entire Joint Pulled on Testing Machine).*

Pipe Size, O. D., 12.75 In.; Wall Thickness, 0.375 In.; Carbon Content, 0.06. Open-hearth Steel.

Test Number	Tensile Strength, Tons: Pipe	Tensile Strength, Tons: Welded Joint	Efficiency of Welded Joint Per Cent
1	410.57	363.00	88.41
2	401.90	348.00	86.58
3	386.78	332.00	85.83
Average.....	399.75	347.66	86.97

All other items, such as supervision and overhead, were considered even, and thus eliminated in the comparison. The results obtained were as follows:

1. *Labor.*—Electric welding costs are 25 per cent greater than gas.

2. *Generation.*—Electric welding costs are 61 per cent less than gas.

3. *Welding Wire.*—Electric welding costs are 40 per cent less than gas.

4. *Depreciation.*—50 per cent per year was allowed on the machinery for electric welding, and it was conceded that there was no depreciation on the generators and equipment for gas welding.

Considering only the items listed, the electric-welded joint shows a total saving of 22 per cent in comparison with the gas-welded joint. We believe that these figures are fairly accurate, and as accurate as can be determined at the present time.

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Conclusion

Considering the great amount of pipe that has been electric-welded within the period of only one year, it is natural that we believe that during that time much progress has been made in the welding of pipe lines. Those who have had the privilege of being connected with the electric welding of these lines have had much to learn, and what they have learned in this past year should certainly encourage them for the future. We believe and predict that the electric welding of pipe lines has only started, and that with improved machinery and improved welding rods the time for welding each joint will be greatly reduced, and the cost of the welding reduced in proportion.

Acknowledgment

The writer wishes to thank the executives of The Texas Pipe Line Co. and The Texas-Empire Pipe Line Co. for their co-operation and assistance in the development of many of the methods described above, and also for their courtesy in furnishing many of the data and photographs contained in this article.

Discussion

MR. W. G. HELTZEL'S discussion is here summarized. Great advances in pipe line construction methods have taken place in the last three years. An outstanding development within the last year has been electrically welded lines. It has been my observation that the old pipe-line crews were better organized than construction gangs of today on gas or electric welded lines. More screwed pipe could be laid under the worst weather conditions than is the case today with gas or welded lines. A few days of heavy rain, followed by sub-zero weather, seriously retarded construction work last winter on a pipe-line project because of ice which formed and filled the 200-ft. sections of welded line. Had this been a screwed line, the weather would not have prevented the pipe line crews from laying pipe, consequently work would have gone along with little or no interruption. The gas or electric welded line, I believe, is better than a screwed line, but the methods of organizing and handling of labor, are less efficient in welded than in screwed lines.

A slide was thrown on the screen showing the method of strapping welds on river crossings used by the Sinclair Pipe Line Co. Four straps are used to reinforce the weld. Under a pull of about 195 tons the pipe failed outside the joint, but the welded strap joint held intact.

In taking up old screwed lines, corrosion was found where there was a leak. Corrosion would eat through the walls of the pipe in about three years. Welded lines will eliminate this trouble. Several samples of four-inch pipe were exhibited showing how corrosion had started at tong marks on the pipe.

In regard to testing lines with water after completion, the Sinclair Pipe Line Company recently laid 600 miles of welded line and no water was used to test it. As soon as completed a line is filled with oil to operating pressure. In 200 miles of line, not even a sweat in a weld was found. In the remaining 400 miles two failures occurred at welds which were due to negligence in tossing the pipe line into the ditch. Sub-zero weather precludes testing a line with water. I am convinced that water tests in welded lines are unnecessary and that it is safe to put oil into the line at operating pressure. Go-devils or scrapers were run through the entire 600 miles of line and in no case had a scraper hung up.

One marked advantage of electric welding is that it permits welding work on an operating pipe line. Some companies now weld up the pits with the electric torch, and it is reported that one company is placing patches over weak spots with the electric torch. The overall cost of the welded line is less than that of a screwed line.

Mr. Price then stated that 140,000 welded joints were made during the year, and out of these 140,000 joints only 18 leaks were discovered. In West Texas a 50-mile line showed no leaks when oil was pumped through.

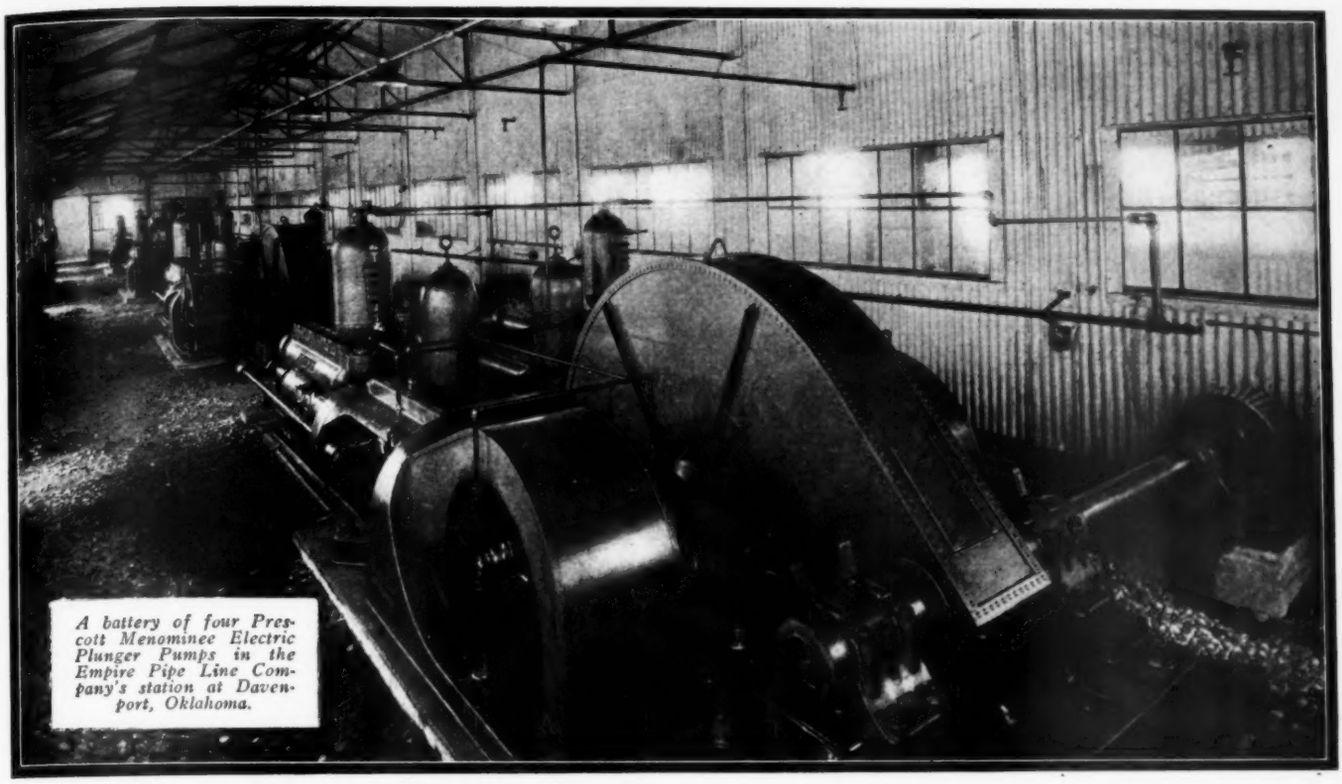
An interesting point was brought out in the discussion in answer to a question by Mr. Suman as to the cause of corrosion at coupling oil leaks in a screwed line. Mr. Heltzel thought it might be due to the action of bacteria in the oil-soaked soil. Mr. Knappen of the Gypsy Oil Co. said the Gulf Co. also found that pipe that had been in service 15 years, and then had been replaced on account of coupling leaks, corrosion sufficient to cause replacement in three years occurred unless care was taken to remove all the oil soaked soil to prevent it coming in contact with the pipe.

CORROSION OF OIL STORAGE TANKS

VALUABLE information bearing on the subject of oil storage tank corrosion, a matter of vital interest to the petroleum industry, is being obtained in the course ot an investigation being conducted near Borger, Texas, by the Petroleum Experiment Station of the United States Bureau of Mines, Department of Commerce, Bartlesville, Oklahoma, and the State of Oklahoma. This investigation is being conducted in co-operation with the Gulf Oil Company, the Parkersburg Rig and Reel Company and the Aluminum Company of America. The great interest manifested by the petroleum industries in the subject of oil tank corrosion is probably due to several causes; first, the development of fields in which high-sulphur petroleum and hydrogen sulphide-bearing gases are being produced, and second, the use of vapor-tight tanks, as corrosion often takes place to such an extent that vapor-tight tanks become leaky. The tank battery upon which the observations are being made is located about two miles north of Borger, on a lease belonging to the Gulf Oil Company. The battery consists of one 500-barrel all-aluminum flow tank, two 250-barrel all-aluminum stock tanks, and two 250-barrel all-steel stock tanks.

To carry on this investigation a fully equipped laboratory for making water analyses, photomicrographs, gas analyses, and various sulphur determinations for water, oil and gas has been established on the lease. In addition to the various chemical determinations many observations are continually made on the tank battery itself. Each tank is equipped with ten thermocouples located at various strategic points, the temperatures being determined at regular intervals with a potentiometer. Each tank is also equipped with mercury-actuated recording thermometers. Complete records are maintained of the actual operating conditions in each tank, for example, if the tank is filling with crude oil, standing full, being emptied by the pipe line, or standing empty. Humidity determinations are made on the vapors in each tank. Test strips are suspended in two of the tanks; aluminum strips in one and steel strips in the other. At the end of each 60-day period a test strip is removed from each tank to provide specimens for tensile strength determinations and microscopic studies.

THE Department of Engineering Research at the University of Michigan, Ann Arbor, Mich., is now equipped to make certified tests of samples of gasoline for knock rating on our N. A. C. A. Universal test engine. Standard A. S. T. M. distillation and gravity determinations will also be included. This service will be under the personal direction of Professor George Granger Brown whose work on motor fuels is already so well known to the industry.



A battery of four Prescott Menominee Electric Plunger Pumps in the Empire Pipe Line Company's station at Davenport, Oklahoma.

NON-STOP SERVICE
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And you can save money, too, with these dependable pumping units. They require less power and maintenance charges are reduced to an absolute minimum.

Send for performance records, catalogs, or any information you need to help you lick your pumping jobs. Our engineers will be glad to advise you without obligation of any kind.

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Pumps for deep mines ~ Pumps for pipe lines

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OPEN UP THE HOLES

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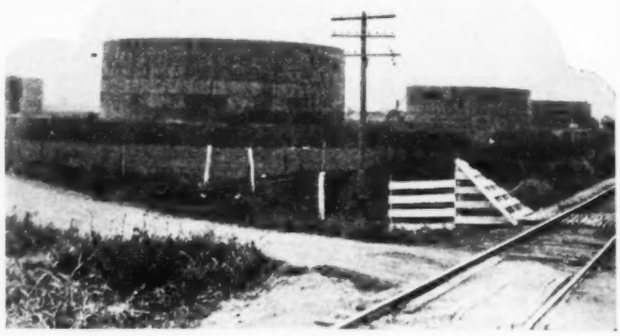
"Used where performance counts"

Empire Makes Record In Building Steel Storage.

AT a time when facilities for caring for production in the Oklahoma City field were painfully cramped, the Empire Gas & Fuel Co., by necessity, established a tank construction record. Its Bartlesville engineering staff rose to the occasion by having 320,000 barrels of steel tankage erected in 20 days overall time. At the same time another record was registered when the pipe line department increased, in 11 days, a 22,000-barrel line to 40,000 barrels daily.

The emergency arose when the Indian Territory Illuminating Oil Co., a producing subsidiary, brought in new production that temporarily swamped transporting and storage facilities.

The order for the increase in line capacity was approved on July 29 and two days later materials for the installation of additional pumping units were received. Two centrifugal pumps, operating in series, were installed at the Oklahoma City station, a couple of more of the same type pumps put in at Cimmarron station, and a new two-unit centrifugal



station built at Edmond, Okla. On August 11 the work was completed and the line started handling 40,000 barrels daily.

The more impressive record was in the erection of the four 80,000 barrel capacity tanks, during which work, in the language of superintendents, the steel was "man handled". The order for the steel was given the Kansas City Structural Steel Co. late in the afternoon and the next morning the Empire company started the tank grades.

No delays of any nature were experienced. The steel company insured against delays in delivery of material by having men ride the trains on which shipments were sent from Kansas City to Oklahoma City. During the peak periods of the work the construction company employed around 200 men. All of the tanks were completed in a spread of 20 days against an estimated time of 30 days for each tank. When a tank was completed it was filled then pumped down and leaks caulked.

Construction work on the first tank started August 4 and the tank was completed 10 days later. The second was started August 6 and ready 12 days later; the third begun August 9 and finished in 11 days, and the fourth was started on August 14 and finished August 24.

All parts were fabricated at the mill. Plates for the bottoms and sides were riveted and the roofs welded.

New Oklahoma Plant Now Operating.

The new plant of Crosbie, Porter & Martin, Inc., of Tulsa, in the Cary pool of Oklahoma near Okemah, has been completed and is now operating, making approximately 7,000 gallons of gasoline daily, although it has a capacity of 15,000 gallons daily.

When writing GRANT OIL TOOL CO., *please mention The Petroleum Engineer*

Two New Corporations Formed

E. I. Hanlon

A NEW supply firm known as Hanlon - Waters, Inc., has been formed in Tulsa, Okla., and is now handling the following well-established lines of petroleum specialities: Victaulic couplings, Reed air filters and Fisher pressure regulating equipment.

The firm is composed of E. I. Hanlon, M. F. Waters, D. E. Buchanan and J. H. Boyle, who are chairman of the board, president, vice-president and secretary-treasurer, respectively. Associated with them in sales capacities are Chester Herndon and Bob Armitage. The entire personnel of this company has long been identified with the petroleum industry and enjoys an extremely wide acquaintance.

An affiliated company known as Hanlon - Buchanan, Inc., has also been formed to process natural gasoline for coast-wise and export shipment; to utilize the lighter hydro - carbons such as butane and propane along some new lines, and to sell the conventional grades of natural gasoline.

M. F. Waters

A processing plant is being built by Hanlon - Buchanan at Good Hope, Louisiana, and general offices are in Tulsa where the company is ready for business. A program is being developed to acquire natural gasoline production, which, with purchases from present producers, will supply material for their operations.

D. E. Buchanan

The plant with a complete terminal at Good Hope will process conventional grades of natural gasoline into a highly volatile yet stable gasoline which can be shipped in cargo, according to officials of the new company, with no more loss than attends shipping motor fuel. The cargoes will be shipped in the coastwise and export trade.

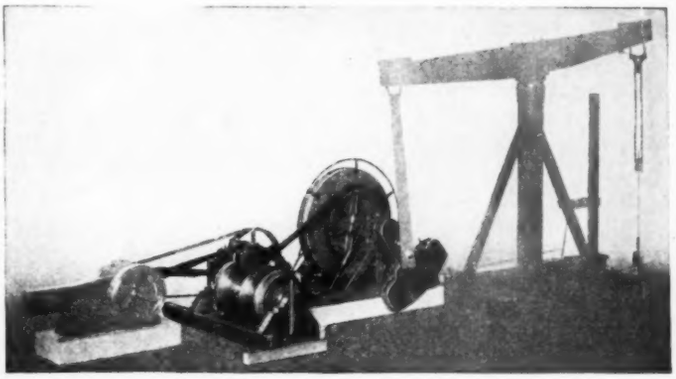
Mr. Buchanan was one of the first men in the industry to develop an export market for natural gasoline. He has been an exponent of the idea that the industry must diversify and expand its markets through manufacturing special products. According to his views since the present natural gasoline market is subject almost entirely to demands for blending natural gasoline and refined products, anything accomplished in diversifying or expanding the demand in other channels will benefit the natural gasoline industry.

J. H. Boyle

OCS

Universal Rig Fronts

Request Bulletin 85



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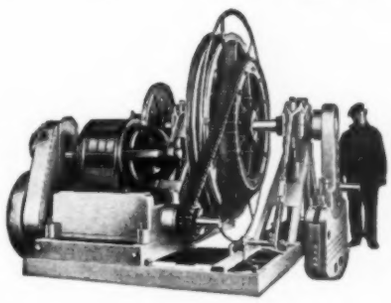

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THE OIL COUNTRY SPECIALTIES MFG. CO.

Coffeyville, Kansas

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HILLMAN-KELLEY, Inc.
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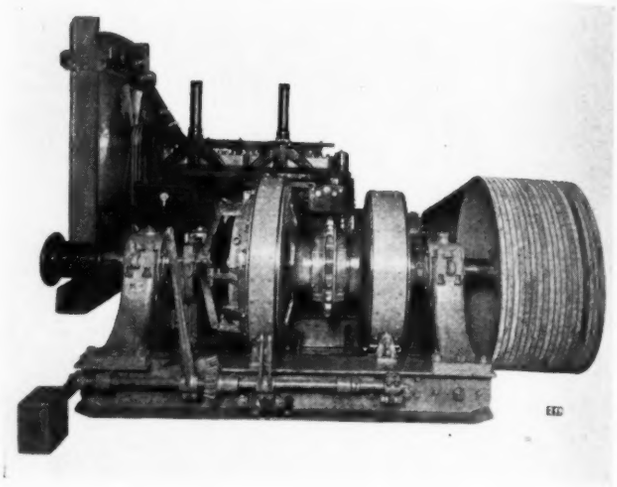
New Type Rotary Outfit Being Developed

Designed for Deep Drilling and Powered with Internal Combustion Engine



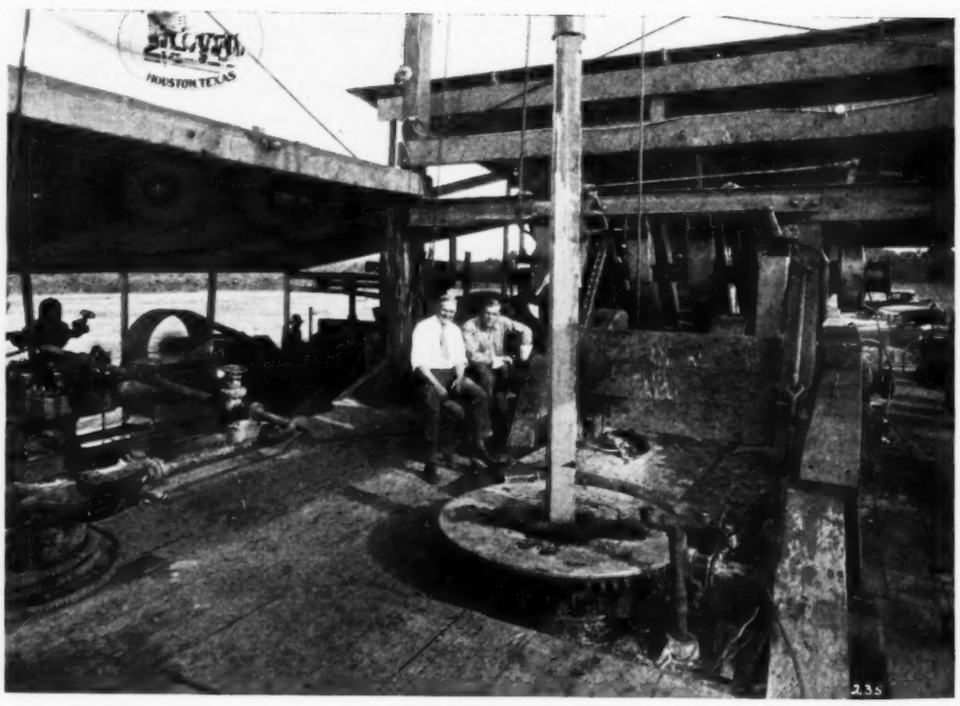
AN INTERESTING method of drilling is now being used by several of the larger oil producing companies in the Mid-Continent field. It is the Portable Rig Co.'s rotary outfit which is powered by Waukesha motors. For many years the Portable Rig Co. has specialized in outfits of this character which were designed for comparatively shallow drilling, but recently, in conjunction with the Waukesha Motor Co., a great amount of experimental work has been done in developing an outfit which may be used in the drilling which steadily continues to get deeper.

This type machine was first used in the Mid-Continent near Cushing, Okla., where a well 3,104 feet deep was drilled, using natural gas as fuel for the motor. Since that time, one well was drilled near Perry, Okla., to a depth of 4,343 feet, using gasoline as fuel. Several installations of this nature have been made in Kansas. The first was a well drilled by the Barnsdall Oil Co. in the western part of the state which reached a depth of 3,600 feet. A well now drilling near Caldwell, Kansas, is close to 4,000 feet in depth, and is destined for 5,100 feet, while a wildcat venture in Reno County, Kansas, will go to 4,800 feet, the present depth of the test being about 1,100 feet. In all of these installations gasoline was used for fuel.

Some very interesting fuel costs per foot have been established through the use of this type equipment. When the machines used natural gas for fuel, the average fuel cost per foot drilled is reported as $0.296; and when the motors were run on gasoline, the same cost was reported as $0.822 per foot.

In arriving at these power costs, the charge for the consumption of natural gas was twenty cents per thousand, while the cost of the gasoline was computed from the use of commercial gasoline at retail prices.

In particularly arid regions where water often constitutes a genuine problem, these machines are said to have become very popular on account of the low rate of water consumption necessary. The average daily water consumption necessary for drilling with this equipment is placed at two hundred barrels.



Air lines of the United States, with a flying mileage of more than 10,000,000 miles annually, have created a demand for more than 1,000,000 gallons of gasoline and 250,000 gallons of lubricating oil.

An Office on the Road

BUSINESS men traveling the Southwest will find at Houston a hotel designed to meet the requirements of a business address far from home.

Comfortable bed room and bath suites . . . spacious sample rooms . . . every wanted service within the building and a location in the heart of Houston's commercial district.

Experienced travelers in this territory make it their home. It is an especially convenient point from which to cover the rich East Texas shipping and oil interests.

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The RICE HOTEL

"Largest in Dixie" — 1000 Rooms

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IF YOU have some such job—and most every gasoline plant has—put it up to a regulator that is:

—made to hold back pressures from 300 to 800 lbs.
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—or to discharge intermittently into especially low pressure or very high pressure distributing systems.

That's the field of service the C-F BACK PRESSURE REGULATOR is expressly made to cover. And cover it, it does, to perfection—and to the general satisfaction of the gasoline manufacturing industry.

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YOUR PIPE WITH

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TRADE MARK

The Original Rust Preventive

the proven long-time chemical and mechanical protection.

Save Freight, because less tonnage is required per mile of line.

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Save Your Pipe with the Positive Protection of NO-OX-ID

NO-OX-ID and NO-OX-IZED Wrapper are being applied to meet the most severe conditions at a cost of 50% of many other coatings.

The real cost of protecting steel pipe line should be based on the cost of the line in the ground.

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Many Operating Difficulties Found in

Handling Gas Well Craters

DOWN in the north central part of Louisiana, they are accustomed to handling big gas wells, for in that part of the Mid-Continent field are located two of the world's largest gas reserves, the Monroe and Richland fields, respectively. The field forces of this region take the matter of big gas wells as just a part of the day's work, but there are times when the best of regulated plans go astray; and the photographs which accompany this story illustrate some instances which taxed the mechanical ingenunity of all concerned when some gas wells became contrary and went "hay-wire."

While they are not encountered every day, craters which are formed by wild gas wells are no novelty in these fields. The wells are drilled in after ample mechanical and engineering precautions have been taken; but once in a while the gas is just too much, and it breaks out on the outside of the casing. The extremely heavy pressure and rate of flow soon make their energy apparent on the ground around the casing, and small portions of the ground are removed by the force of the gas. This is the starting of the crater, and the continuation of this process results in some damages which are exceptionally costly to the operators, as well as establishing extremely dangerous conditions.

One of the largest craters encountered is the Thomason C-2 in the Richland field, which is pictured below. It was very difficult to handle, and in order to relieve the pressure of the gas, some wells were drilled near by. It was hoped that by completing other wells to the sand which produced the gas, that the crater would diminish in pressure, but the completion of three other wells on adjacent locations failed to make any appreciable difference in the cratered gas well.

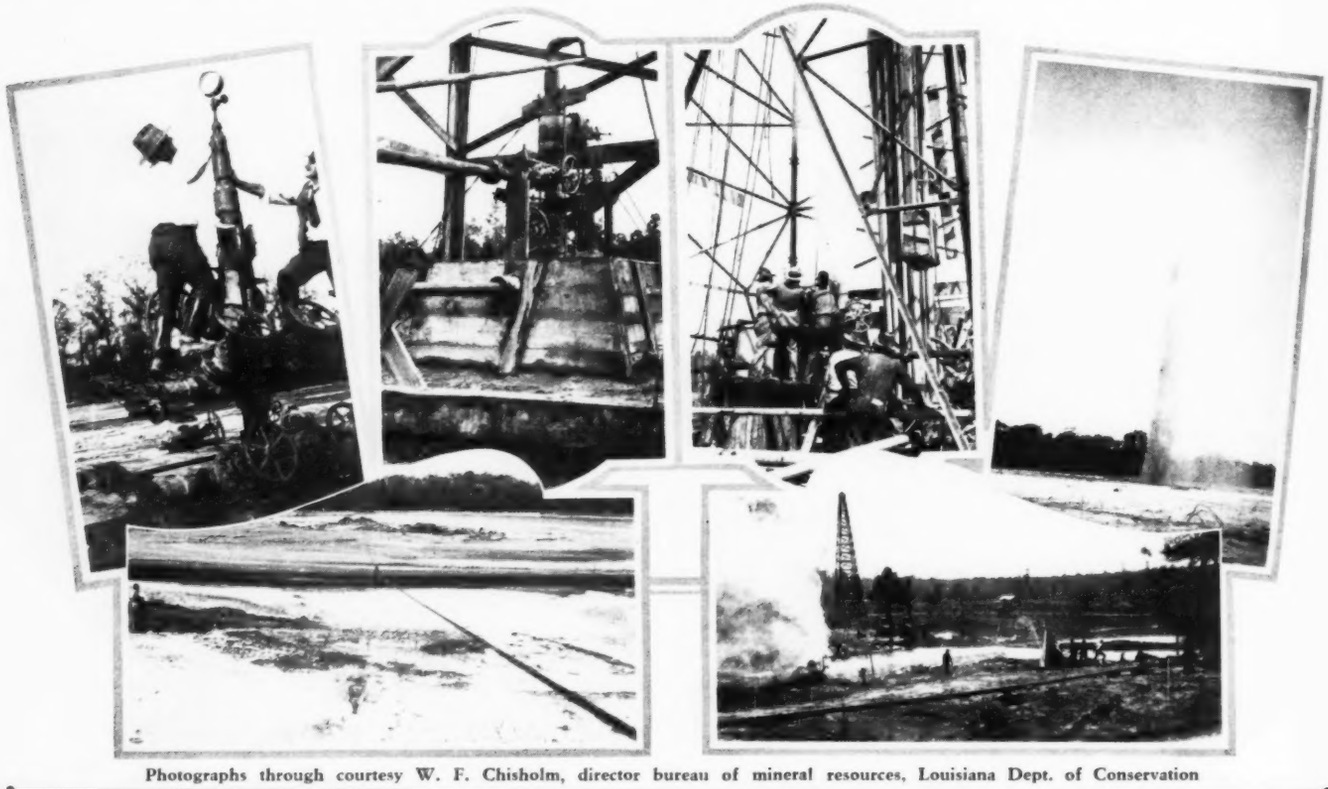
The picture on the upper right shows the Thomason C-2 just as the surface pipe was being lost below the surface of the ground. The surface pipe gradually sunk out of sight, and the spout which appears is a combination of gas, sand and water which resembles a geyser. The picture on the lower left shows the crater when it had attained its full width of 180 feet in diameter. In an effort to test out the depth of the crater, a cable was strung across it from small dummy derricks. Attached to the cable was a pulley attachment containing a metal weight of 450 pounds. The weight was blown about like a cork, and never was put below the surface. After several attempts to lower the weight, it was removed, and a steel shaft weighing 850 pounds was utilized. This amount of weight proved sufficient to plumb the depths of the crater, which varied from five to 28 feet.

The picture on the upper right shows W. F. Chisholm, director of the bureau of mineral resources of the Louisiana Department of Conservation inspecting the gauge of a gas well which has just been brought under control. Mr. Chrisholm, on the left, is being assisted by J. S. Ross, petroleum engineer of the U. S. Bureau of Mines.

The picture next to the upper left shows how a big gas well which had faulty connections was brought under control. This well had a very heavy pressure which developed some leaks in the fittings, and in order to eliminate any damage a solid base of concrete was poured around the fittings. This system worked.

Third from the left in the upper row of pictures shows a well which had such a heavy pressure that five men were required to hold the Pitot tube over the casinghead.

The lower right picture shows the famous well shooter, Tex Thornton, coming back just after he has placed a shot over a burning gas well. The shield shown offers protection for a group of men who continued to play a stream of water on Tex as he advanced and placed the shot.



Photographs through courtesy W. F. Chisholm, director bureau of mineral resources, Louisiana Dept. of Conservation

Cash Prize Contest Closes December 31st

ANYONE wishing to compete for the $500 in cash prizes offered by the Merco Nordstrom Valve Company for appropriate slogans that express the advantages of the Nordstrom Valve, must submit their slogans on or before December 31, as the contest closes on that date. According to the rules of the contest, no one is barred from submitting slogans except employes of the company. Any number of slogans can be sent in by a contestant—but none can be more than ten words in length to receive consideration.

The winner of first prize will receive $250; $100 is to be awarded for second prize and $50 for third prize. There are also four prizes of $10 each and twelve prizes of $5 each—making a total of $500 in nineteen cash prizes to be distributed in the contest.

Complete details of the Nordstrom Valve can be obtained by asking the manufacturers for literature or by interviewing owners and engineers familiar with the valve. Full information regarding this contest may be found on page 52 of this issue. In writing the company, letters should be addressed to 343 Sansome Street, San Francisco.

One of the Skelly Oil Co.'s safety teams in the Earlsboro field of Oklahoma performing some practice work which is now a very important part of the training of all field employees of that company.

From left to right, the team is composed of Lester Alexander, William Garner, J. B. Nobles, assistant captain; L. D. Coldwell and R. O. Tate, while the "victim" is C. V. Dillbeck.

Geophysical Methods of Prospecting for Petroleum

Abstracts of many articles prepared by specialists in this and other countries, dealing with the subject of geophysical prospecting for oil, appear in the monthly publication entitled "Geophysical Abstracts", compiled by Frederick W. Lee, senior physicist, United States Bureau of Mines, Department of Commerce. The latest issue, known as Information Circular 6164, discusses such matters as seismic methods of determining the deviation of drill holes; factors in design of portable field seismographs; the radio-activity of natural gases in the Baku region; the gravity gradiometer, the direct discovery of oil deposits with the aid of electrical methods of prospecting; and the progress of geophysical prospecting in Germany. Persons interested in receiving these abstracts regularly should communicate with the Bureau of Mines.

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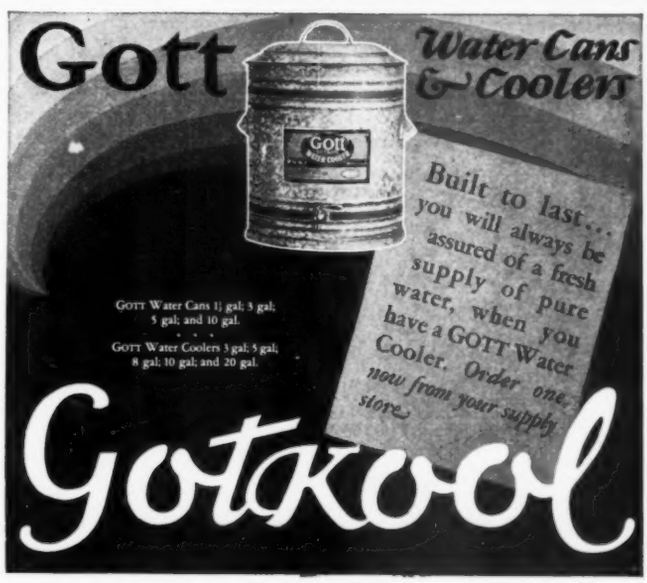
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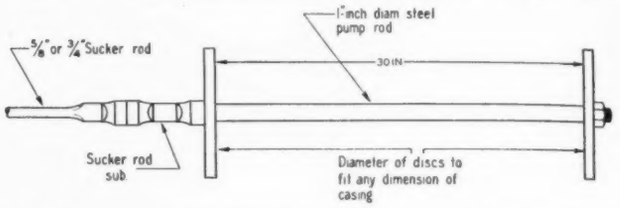
Gauge For Testing Casing at Well

By H. B. Hurley

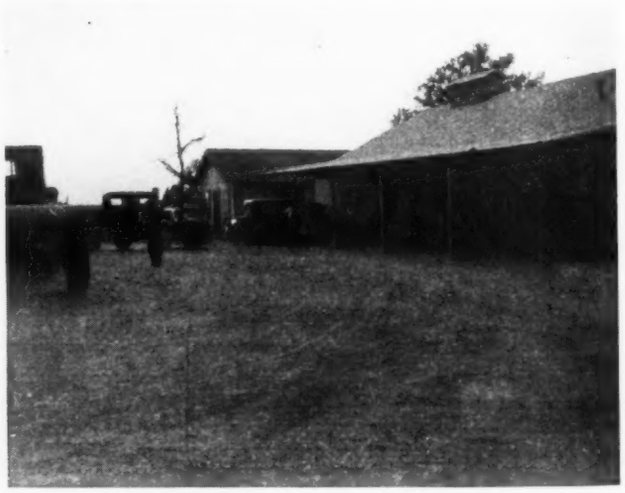
WHEN a long string of casing is to be cemented, it should, just prior to running in the well, be subjected to rigid inspection and tested for any defects arising from mishandling in shipment or in the field. If every long string of casing were gauged at the well before running, an eventual saving of many dollars in time, production, and possibly a string of casing would result because of the added insurance against running flat, blistered, or dented casing in the well.

For testing the inside of casing, the casing gauge shown



in the accompanying sketch was devised. It consists of an old steel pump rod, each end of which is machined to receive a steel disc. One end of the pump rod is threaded to fit a sucker-rod box (see sketch). The sucker rod serves a dual purpose, the box locks the disc on the pump rod, and the sucker rod itself makes a good handle of sufficient length for testing long joints of casing. The steel discs are machined to the desired inside dimension of the casing to be tested. Several sets of discs for different sizes of cases can be made to fit the same pump rod.

It takes three men about two hours to gauge a 4,000-ft. string of casing. While this idea may not be new to many field men, it may have sufficient interest and importance to attract the attention of those men in the field who have anything to do with well casing. More attention paid to handling, testing or gauging of casing immediately before being run in deep wells means less trouble from defective casing before, after, and while running the casing.



The Amwrada Petroleum Corp.'s field garage at Seminole.

Foxboro Issues New Bulletin

The Foxboro Company, Foxboro, Mass., has distributed Bulletin Number 115-2 on Foxboro instruments in the power plant. It contains twenty-eight pages of brief descriptions and applications of various instruments for measuring and recording temperature, pressure, and flow, as they effect the efficiency of the power plant. Copies of this bulletin will be mailed upon request.

When writing McCord Radiator & Mfg. Co., *please mention The Petroleum Engineer*

Russell Manufacturing Co. Receives Large Contract

THE Russell Manufacturing Company at Middletown, Conn., has just received a contract to supply a prominent automobile manufacturer with their new Rusco clutch spider and assembly.

Claims made for this new clutch assembly, which has been perfected and patented by the Russell Mfg. Company, are that it is revolutionary and fool-proof in operation and construction.

Its extremely light weight, flexibility and ability to absorb vibration gives a much smoother engaging action, quicker get-away and far more flexible performance when shifting gears in traffic or when it is necessary to drop from a high gear to a lower one in hill climbing, etc.

Brake Lining Firm Expands

F. A. Gerrard, Pacific Coast manager for the Russell Manufacturing Company, with headquarters in San Francisco, announces another Rusco factory branch, located at 1223 South Olive street. Los Angeles, California.

Kenneth L. Shaw of the San Francisco office has been promoted to Los Angeles as manager of the new branch. Complete stocks of Rusco woven brake linings, Durak brake shoe liners, clutch facings, plates, fan belts, etc., will be maintained.

Less than three years ago Rusco opened the first Pacific Coast branch in San Francisco. At that time the company introduced on the Pacific Coast a new type of moulded shoe brake lining called Rusco Durak brake shoe liner.

Safe Practices in Cleaning Petroleum Stills by the National Safety Council, Chicago, Ill., is an illustrated bulletin giving details for the safe procedure in cleaning shell stills at refineries. The summary is a tabulated list of thirty rules for safe practices in work of this character.

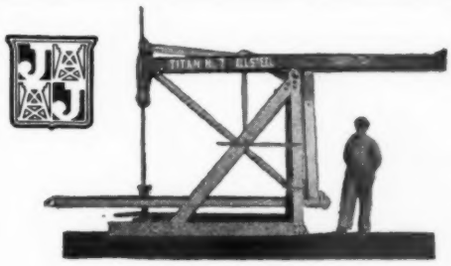
THE October issue, Volume 1, Number 1, of The Petroleum Engineer, was accorded an extremely gratifying reception. Since its appearance, each mail has brought us many congratulatory letters commending the high quality of its editorial content and the excellence of its general make-up.

These letters, coming from oil and gas company operating officials in this and foreign countries, manufacturers, advertising agencies and fellow publishers, evidence a careful analyzing of The Petroleum Engineer and, almost without exception, carry a prediction for the publication's success.

At the recent International Petroleum Exposition, the first issue of The Petroleum Engineer attracted an exceptional amount of attention. Words of favorable comment were to be heard on every hand and sample copies were requested constantly.

We take this means of thanking each one who wrote us or extended his congratulations on our initial number by word of mouth. We hope you like this, the November number, even better.

—The Publishers.



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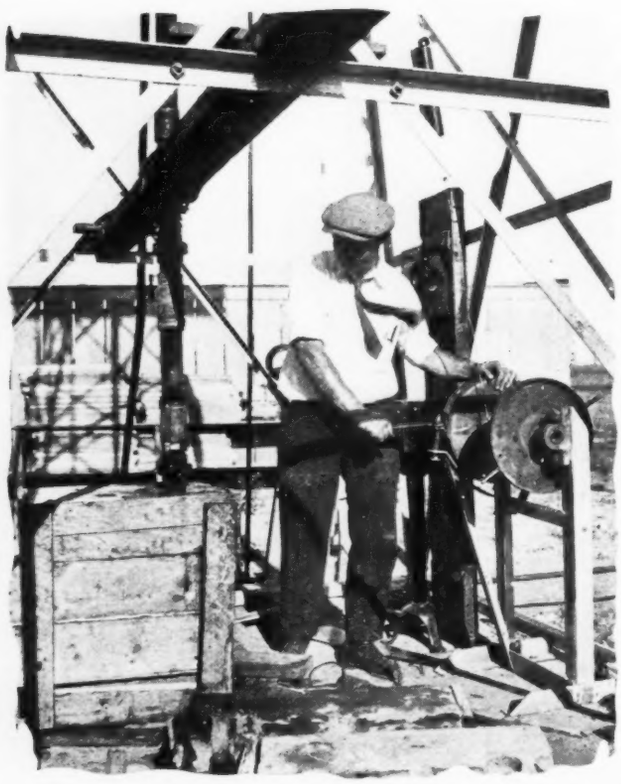
Removing the Kinks From Crooked Holes



Top—R. E. Griffith, petroleum engineer, holding acid bottle container. Left—S. H. Grinnell running the experimental rig.

THROUGH improved drilling methods, developed within the past year, the field department of the Union Oil Company has virtually eliminated the drilling of crooked holes, and in so doing has accomplished something field men have been striving to do for several years.

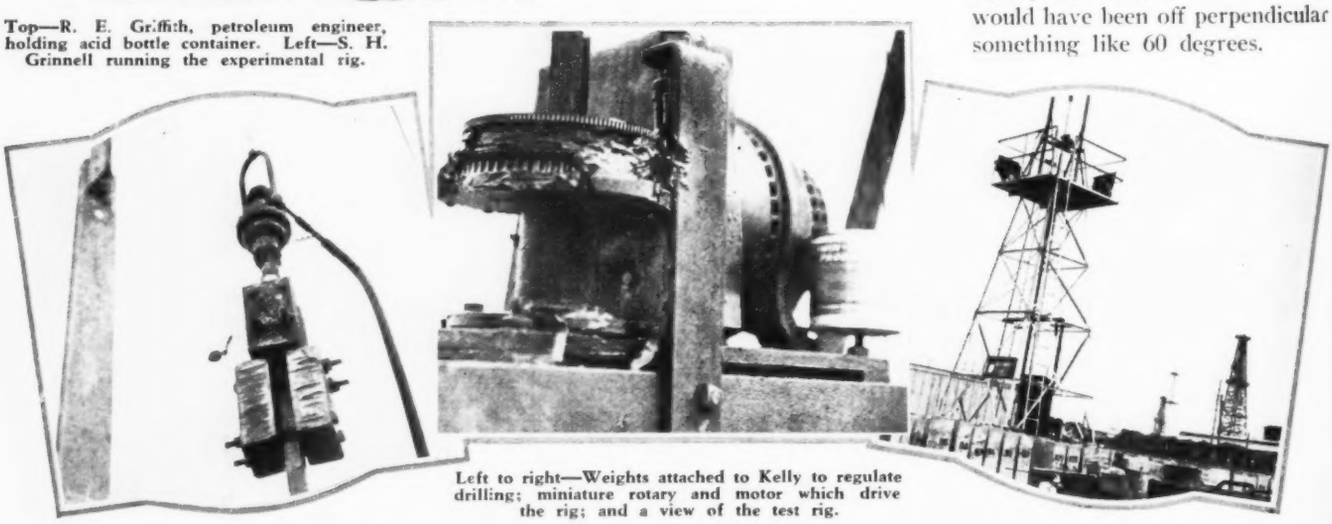
It can be appreciated the vast amount of complications and difficulties a crooked hole, particularly a deep one, can cause. It not only increases the danger of bad twist-offs of drilling pipe and failure of casing, but increases and complicates fishing jobs in general.

There are a number of things which cause holes, started straight, to veer off from the perpendicular. Some of these have been pretty definitely catalogued and measures taken to overcome them. There are still a few which must be subjected to further research, and many fine points to be learned about drilling in general. These drilling problems the Union Oil Company has decided to take to the laboratory. The laboratory in this particular instance is a miniature rig—an Ideco gas trap tower—20 feet high, which has been erected on the Dominguez lease where a series of drilling tests are now being conducted. Drilling tools and equipment used in the rig have been reduced almost to toy size.

From the drilling tests being made at Dominguez it is hoped to determine the effect of formational dips on the drill; what happens when too much weight is placed on the drill; what speed the drill should be rotated at in the various formations to get the best results, and the relationship to be maintained between speed and weight on the drill.

The company has a classic example in its Buell No. 1, being drilled several miles southeast of the present Lompoc field, in how crooked a crooked hole can get, and also the measures now being employed by the field department to straighten holes of this kind.

The Buell well is being drilled in extremely hard formations pitched at varying steep angles. After the well had been drilled to a depth of 1,586 feet the hole began showing signs of being decidedly warped. Before starting to redrill, the fluid in the well was bailed to 235 feet and an electric light run in the hole. At 159 feet it passed out of sight. Subsequently acid bottle tests showed that at 256 feet the hole deviated off perpendicular five degrees. At 650 feet it was off 8 degrees and 30 minutes; at 1,043 feet, 14 degrees, and at 1,571 feet, 20 degrees. Had it been possible to operate a drill in the well to a depth of 5,000 feet at the same rate of curve, the bottom of the hole would have been off perpendicular something like 60 degrees.



Left to right—Weights attached to Kelly to regulate drilling; miniature rotary and motor which drive the rig; and a view of the test rig.

How the Union Oil Co. is Experimenting to Eliminate a Major Problem of the Industry

To straighten the hole the drillers began redrilling with a 14¾-inch rotary shoe at 30 feet. With a rotary shoe it was found possible to cut into the walls of the hole to obtain a shoulder on which to drill. The hole was carried down to 150 feet with the rotary shoe. At the point where the original hole had first started to curve badly it was discovered, by means of the electric light run down in the hole, that it was again starting to deviate from the perpendicular.

When the hole reached a depth where the electric light could no longer be used accurately the drillers began making acid bottle tests.

The development of the acid bottle testing device, now being used by the Union Oil Company, is credited to "Hy" Winter, petroleum engineer at Santa Fe Springs.

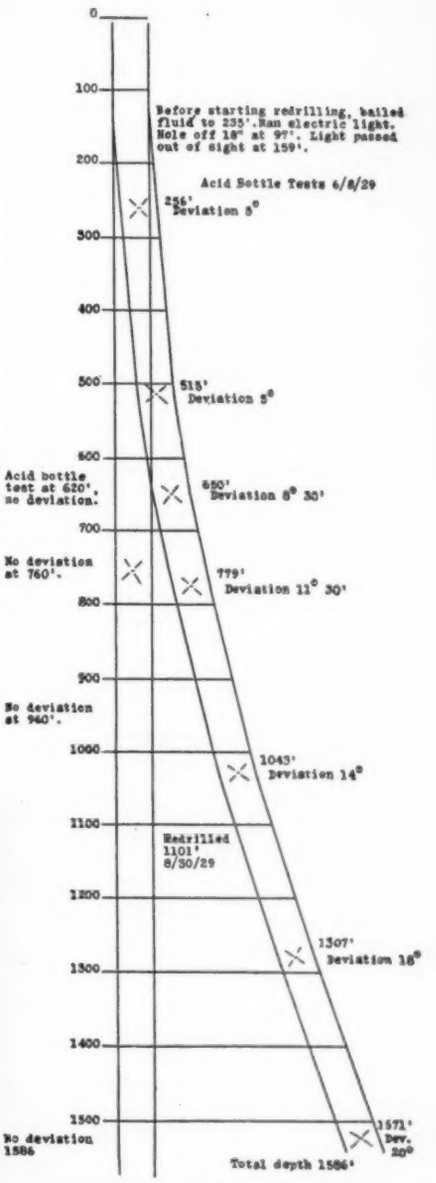
Going back to the Buell well, it was found that at approximately 650 feet, the drill passed completely out of the original hole.

At the time this data was obtained for publication the bottom of the redrilled hole was 1,690 feet and there was no deviation at that depth. Between 1,101 feet and 1,690 feet it was found necessary to correct for an occasional bend that appeared in the hole.

In straightening the hole it was found that by using a rotary shoe, taking most of the weight off the drill and rotating it at a faster speed than used ordinarily, the bit would cut its way into the wall of the hole, and after establishing a shoulder would keep the hole straight. This has resulted in all drillers being cautioned to keep a close check on the weight maintained on the drill stem.

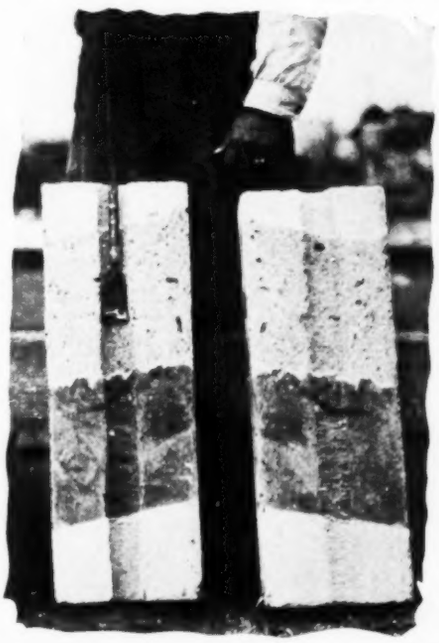
All wells being drilled by the Union Oil Company are being checked by means of the electric light at the shallow depths and by the acid bottle test as soon as they get too deep to use the light. By this means the kinks in the wells are discovered while it is still possible to correct them. While keeping the holes straight has cut down on the average distance drilled each day, the loss in "yardage" is by no means comparable with the benefits gained.

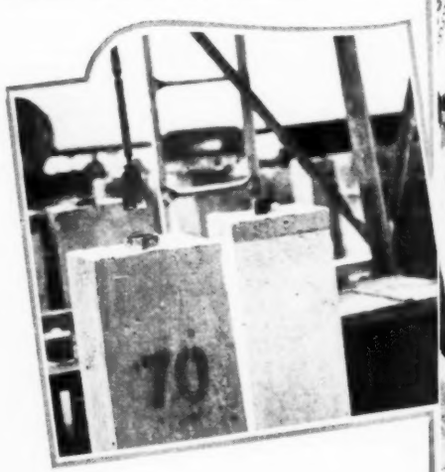
The equipment used in this experimental work was built up by S. H. Grinnell and E. P. Tallant.



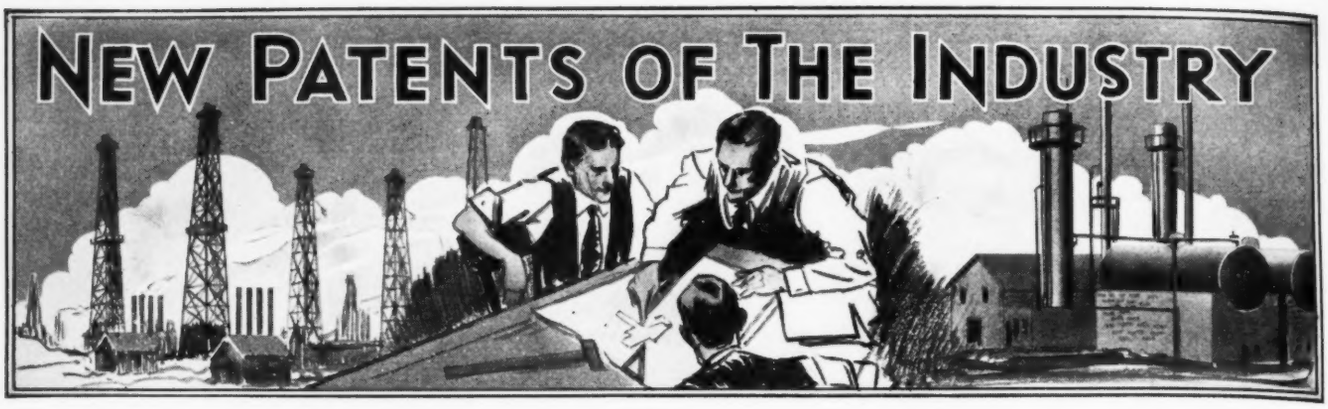
DRILLING CHART BUELL NO. 1

Diagram on the right shows appearance of well as it was originally drilled, and the one on the left the way it looks since being redrilled.

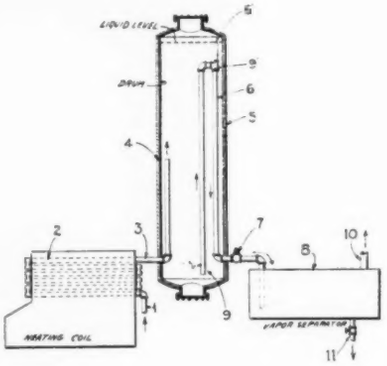




Left—These test blocks were made of sand, gravel, and cement in order to imitate underground conditions. Bottom—Views of the small tools used in this experimental work.

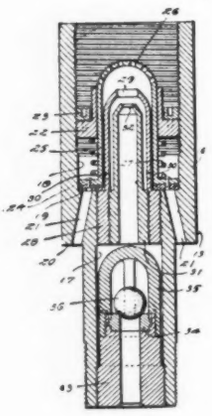


1,725,434. METHOD AND APPARATUS FOR CONVERTING HYDROCARBONS. Louis J. Walsh, Belmont, Mass., assignor to Standard Oil Development Company, a Corporation of Delaware. Filed Nov. 28, 1923. Serial No. 677,364. 9 Claims. (Cl. 196—58.)



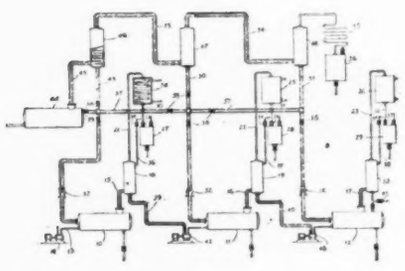
6. In a method of withdrawing converted hydrocarbon material from a reaction drum, the improvement which comprises settling tarry material during the conversion, withdrawing vapors from near the top of the drum, combining the withdrawn tarry material and vapors into a single stream, and reducing pressure on the withdrawn stream.

1,723,992. OIL-WELL PUMP. Lee J. Black, Beaumont, Tex. Filed Jan. 4, 1928. Serial No. 244,495. 5 Claims. (Cl. 103—233.)



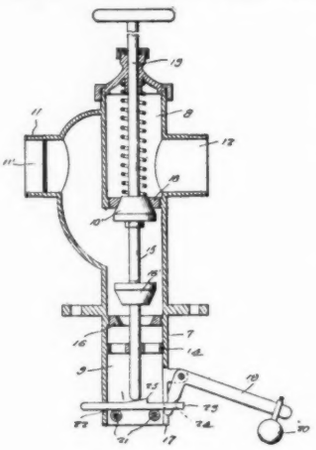
1. In well pumping apparatus, a conduit communicating at its lower end with fluid in the well, said conduit having nozzle structures at spaced intervals.

1,724,760. PROCESS AND APPARATUS FOR THE CRACKING OF HYDROCARBON OILS. George William Gray, New York, N. Y., assignor, by mesne assignments, to The Texas Company, New York, N. Y., a Corporation of Delaware. Filed Oct. 28, 1924. Serial No. 746,298. 6 Claims. (Cl. 196—49.)



1. The process of converting heavy hydrocarbon oils into oils of lower boiling point which comprises subjecting oil to a cracking temperature and pressure in a pressure zone, separating the high boiling fractions of the evolved vapors from the low boiling fractions in the form of a condensate, then subjecting the condensate while still hot to increased cracking temperature and pressure, simultaneously distilling another independent body of oil, separating the evolved vapors according to their boiling points, and co-mingling the condensate thus formed with the oil in one of the pressure zones.

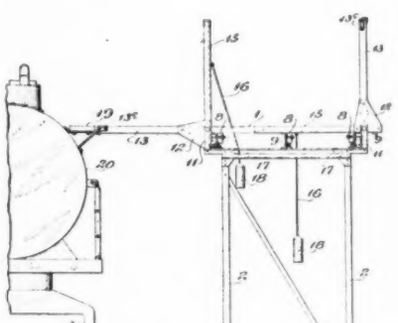
1,732,107. VALVE FOR OIL-DISTRIBUTING SYSTEMS. Oliver Morgan and John W. Stark, Wewoka, Okla. Filed Oct. 20, 1928. Serial No. 313,802. 1 Claim. (Cl. 137—68.)



In a valve of the character described, a body member having an inlet passage and a pair of outlet passages, valve seats within said passages, a valve stem movable through the body member and having valve heads for alternate engagement with said seats for alternate opening and closing of the outlet passages, means normally urging the stem in one direction, a sliding member associated with the body at one end of the stem, and against which this end of the stem is normally contacting by reason of said means, fluid control means for sliding the plate in one direction, said plate being provided with an opening through which the adjacent end of the stem will be projected when the plate is automatically moved in that direction.

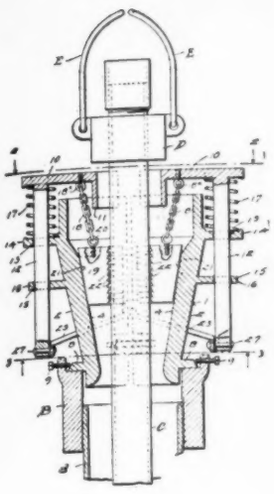
1,723,885. LOADING PLATFORM. Alfred B. Patterson, Tulsa, Okla. Filed Oct. 25, 1927. Serial No. 228,595. 4 Claims. (Cl. 14—71.)

1. A device of the character described comprising an elevated platform, guide rails for the opposite sides thereof having a plurality of equi-spaced ways formed therein, combined gates and walkways pivoted to the opposite sides of the platform adjacent each of said ways, said combined gates and walkways each consisting of bracket arms pivotally engaging adjacent portions of the platform, arms rigidly connected to said bracket arms and planks fixedly secured to said last mentioned arms, other arms fixed to and arranged at substantially right angles to each of said combined gates and walkways adjacent their respective bracket arms, said combined gates and walkways being adapted at times, to be arranged in substantially horizontal positions and extended outwardly from their adjacent portions of the platform, and means connected to each of said combined gates and walkways for normally and automatically returning same to positions between the opposite sides of their respective ways and at substantially right angles to the platform.



1,731,263. COUNTERBALANCE. John B. Picard, Toledo, Ohio, assignor to The National Supply Company, Toledo, Ohio, a Corporation of Ohio. Filed Feb. 8, 1927. Serial No. 166,651. 7 Claims. (Cl. 74—71.)

7. The combination of a shaft, a counterweighted crank member united thereto and having provision for attaching a pitman thereto, a counterweight member loose on the shaft and adjustable angularly around the shaft, and means securing the loose member to the first member at any one of a plurality of angularly adjustments therewith.

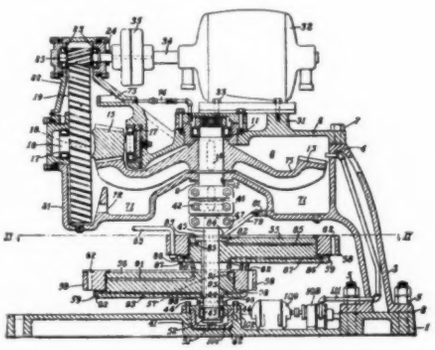


1,725,666. TUBING OR PIPE PULLING SPIDER. BERT H. MORROW, Corsicana, Tex., assignor of one-third to O. B. Harlan, Corsicana, Tex. Filed May 17, 1928. Serial No. 278,505. 3 Claims. (Cl. 24—263.)

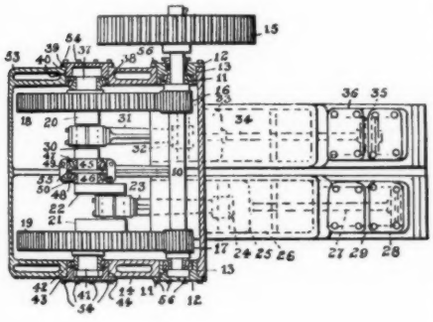
1. A tubing or pipe pulling spider, comprising a tapered tubular housing formed of hingedly engaged sections, means to secure the sections together, said housing being adapted to seat on a well casing head, a sectional cover, depending arms on said cover, flanges on the housing sections having openings slidably receiving said arms, resilient means normally raising the cover relatively to the housing, tapered slips engaging the housing and adapted to engage a rod or tube, flexible elements connecting said cover sections and slips, and means engaging said arms to actuate said cover against the resistance of said resilient means to permit the slips to move by gravity into engaging positions.

1,731,885. MULTIPLE PUMPING-GEAR UNIT. LELAND F. BURNHAM, Pittsburgh, Pa., and PAUL W. JONES, Los Angeles, Calif., assignors, by mesne assignments, to Westinghouse Electric & Manufacturing Company, a Corporation of Pennsylvania. Filed June 18, 1927. Serial No. 199,848. 6 Claims. (Cl. 74—14.)

1. In a drive mechanism for oil-well pumps, a base member, supporting pedestals mounted thereon, a housing supported upon said pedestals, a vertical shaft journalled in said housing and an eccentric shaft journalled in said base and detachably secured to said vertical shaft, said eccentric shaft being disposed between the base and the housing.



1,732,424. POWER-DRIVEN SLUSH PUMP. JOHN A. YOUNG, Torrance, Calif., assignor to The National Supply Company, Toledo, Ohio, a Corporation of Ohio. Filed Apr. 20, 1928. Serial No. 271,436. 2 Claims. (Cl. 74—14.)

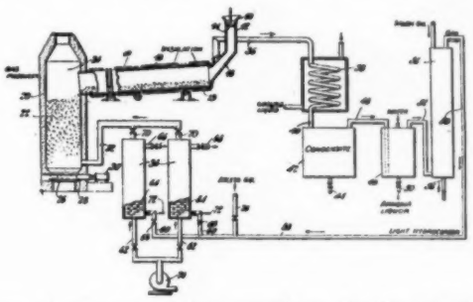


1. In a pump, a casing having two holes in integral portions of its sides, a bearing support between the holes, two separate crank shafts, bearings in the holes to support the outer ends of the crank shafts, bearings carried by the said central support for supporting the inner ends of the crank shafts, a pitman actuated by each crank shaft, and a pump piston operated by each pitman, the inner ends of the shafts projecting sufficiently so that, when the inner end of either shaft is in the center support, the outer end thereof may be arranged in position to enter the adjacent hole in the casing.

1,731,930. METHOD FOR PERFORATING PIPE OR THE LIKE. IRA J. MCCULLOUGH and MILLARD SUMTER BLACK, Huntington Park, Calif. Original application filed Mar. 15, 1924, Serial No. 699,460. Divided and this application filed Nov. 3, 1926. Serial No. 145,960. 6 Claims. (Cl. 29—163.5.)

1. The method of forming a perforation in a completed pipe, or the like, which includes, cutting an elongate slot in the pipe from its exterior, and then beveling away one side of the slot inwardly from the exterior of the pipe.

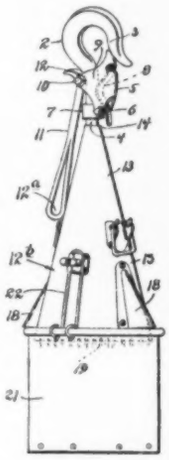
1,732,219. PRODUCTION OF HYDROCARBONS FROM OIL SHALE. AUGUST P. BJERREGAARD, Okmulgee, Okla., assignor to Doherty Research Company, New York, N. Y., a Corporation of Delaware. Filed Nov. 18, 1924. Serial No. 750,574. 1 Claim. (Cl. 202—6.)

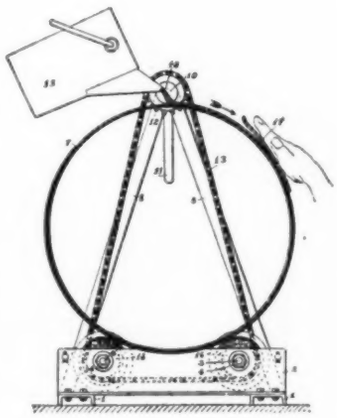


A process of treating oil shale comprising distilling oil shale in an agitated condition by passing a heated gas into direct contact with the shale, discharging the distilled shale into a producer, treating the distilled shale with preheated air to form the said heated gas, condensing vapors from the gas used for distillation, and burning the uncondensed gas from the condenser in a regenerator for preheating the air used in the producer.

1,732,480. SUCKER-ROD HANGER. OSCAR B. LYON, Holtville, Calif., assignor to A. B. Baust and J. J. Richart, Whittier, Calif. Filed Apr. 15, 1925. Serial No. 23,296. 4 Claims. (Cl. 211—60.)

1. In a device of the class described, the combination of a safety hook, means comprising a two-part body supported by the hook for carrying a pluralty of chains, the lower part of the body being detachable while in use, a rod gripping clamp mounted on the end of each chain, the lower part of said two-part body being adapted to act as a receiver for the chains when the hanger is not in use.

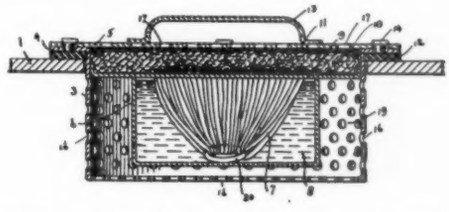




1,733,006. METHOD OF COATING PIPES. HUGH M. COOK, New York, N. Y., and LORLYS R. ROGERS, Cottage Hill, Fla., assignors to Wailes Dove-Hermiston Corporation, New York, N. Y., a Corporation of New York. Filed July 17, 1929. Serial No. 379,003. 2 Claims. (Cl. 91—68.)

1. The herein described method of applying coating material to a pipe, including first revolving the pipe, applying the coating material while hot on the top of the pipe, and applying a pad of non-conducting material in flat contact with the coating material to uniformly spread the coating and to prevent overflow of excess coating.

1,731,406. SAFETY VENTILATOR FOR OIL TANKS. FREDERIK BERNARD, San Francisco, Calif. Filed Mar. 7, 1928. Serial No. 259,616. 6 Claims. (Cl. 220—88.)



1. As an article of manufacture a safety ventilator comprising a multiperforated cage, a fluid chamber fixed in suspended position within said cage, a perforated cover for said cage and spaced from said chamber, absorbent material within the cage and between the chamber and the cover and communicating with the interior of said chamber.

INDEX *to* ADVERTISERS

A

	Page
Ajax Iron Works	15
American Meter Company	118
American Roller Bearing Co.	127
Andrews Steel Co.	11
Atmore, Robt. N. Co.	89
Axelson Machine Co.	123

B

Baker Oil Tools, Inc.	1
Beaumont Iron Works Co.	
Blackor Co.	9
Black, Sivalls & Bryson, Inc.	39
Braun, C. F. & Co.	186
Byron Jackson Co.	179

C

Campbell, J. A., Co.	205
Camp, C. F., Co.	18
Chain Belt Co.	
Chaplin-Fulton Mfg. Co., The	201
Clark Bros. Co.	107
Colona Division Pittsburgh Screw & Bolt Corp.	8
Continental Supply Co., The	69-71
Cooper-Bessemer Corp., The	32-33

D

Dearborn Chemical Co.	201
Doheny Stone Drill Co.	57-58-59-60
Drane-Humphrey Co., Inc.	191
Dresser, S. R., Mfg. Co.	30

E

Elliott Core Drilling Co.	99
Exchange Banks of Tulsa	3

F

Franklin Valveless Engine Co.	85
Frick-Reid Supply Corp.	79

G

Gaso Pump & Burner Mfg. Co.	Inside Back Cover
Gott, H. P., Mfg. Co.	203
Grant Oil Tool Co.	198
Guiberson Corp., The	81

H

Hanlon-Buchanan, Inc.	120-121
Hanlon-Waters, Inc.	66-67
Hercules Tool Co.	86
Hill, Hubbell & Co.	41
Hinderliter Tool Co.	10
Hughes Tool Co.	47

I

International Derrick & Equip. Co.	44-45

J

Jensen Bros. Mfg. Co.	205
Jones, S. M., Co.	54

K

Kennedye-Plumb Corp.	Back Cover
Kerotest Mfg. Co.	195
Kirk-Morrow Iron Works Co., The	6

L

	Page
Lucey Products Corp.	111

Mc

McCord Radiator & Mfg. Co.	204
McEvoy, J. H., & Co.	183

M

Merco Nordstrom Valve Co.	52
Metric Metal Works	118
Miller, Max B., & Co., Inc.	Inside Front Cover
Mission Sales Co., Inc.	
Missouri Portland Cement Co.	91
Moore, Lee C., & Co., Inc.	36-37
Murray Tool & Supply Co.	75

N

National Supply Companies, The	50
National Tank Co.	83
Naylor Pipe Co.	77

O

O. C. S. Manufacturing Co., The	199
Oil Well Supply Co.	62

P

Patterson-Ballagh Corp.	102-103
Portable Rig Co., Inc.	42
Prescott Company, The	197

R

Reed Roller Bit Co.	97-98
Regan Forge & Engineering Co.	49
Reid, Joseph, Gas Engine Co.	130
Republic Supply Co.	93
Resistcor Engineering Corp.	115
Rice Hotel, Houston, Texas	201

S

Skinner Bros. Belting Co.	203
Smith, A. O., Corp.	4-5
Spang, Chalfant & Co., Inc.	64
Spencer Trailer Co.	181
Stoody Co.	7

T

Tulsa Boiler & Machinery Co.	14

U

Union Wire Rope Corp.	13

W

Waukesha Motor Co.	12
Westcott Valve Company	189
Wico Electric Co.	2
Williams Brothers, Inc.	73

Z

Zero Hour Torpedo Co.	16